TMDL for Benthic Impairments in the Accotink Creek Watershed

Fairfax County, City of Fairfax and Town of Vienna, Virginia

Established by the United States Environmental Protection Agency, Region III

/Signed/

Jon Capacasa
Director,
Water Protection Division

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Date

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Established by the United States Environmental Protection Agency, Region III

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Executive Summary

A Total Maximum Daily Load (TMDL) has been established by the United States Environmental Protection Agency (EPA) for the Accotink Creek watershed, located in Fairfax County, the City of Fairfax, and the Town of Vienna, Virginia. Section 303(d) of the Clean Water Act (CWA) and its implementing regulations require TMDLs to be developed for impaired waterbodies. This report addresses two segments of Accotink Creek that have been included on Virginia's 2008 303(d) List of impaired waters for failing to attain the Commonwealth's aquatic life designated use. The lower portion of Accotink Creek, located in Fairfax County, Virginia, was first identified as impaired on Virginia's 1996 303(d) list due to poor health in the benthic biological community. In all subsequent 303(d) lists (1998, 2002, 2004, 2006, 2008), the benthic impairment for this segment of Accotink Creek has remained. In addition, the upper portion of Accotink Creek, located in Fairfax City, Virginia, was also identified as impaired on Virginia's 2008 303(d) list for not meeting the aquatic life use due to poor health in the benthic biological community.

Applicable Water Quality Standards

Water quality standards consist of designated uses for a waterbody and water quality criteria necessary to support those designated uses. According to Virginia Water Quality Standards (9 VAC 25-260-5), the term *water quality standards* "means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."

According to Virginia Water Quality Standards (9 VAC 25-260-10):

> *"All state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be*

> *reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

The General Standard defined in Virginia Water Quality Standards (9 VAC 25-260-20) provides general, narrative criteria for the protection of designated uses from substances that may interfere with attainment of such uses. The General Standard states:

> *"All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life."*

Based on the biological assessment surveys conducted on the stream, the listed segments of Accotink Creek do not support the propagation and growth of aquatic life.

Watershed Characterization

The Accotink Creek watershed is located in Northern Virginia within portions of Fairfax County, the City of Fairfax and the Town of Vienna. The Accotink Creek watershed is located in hydrologic unit code (HUC) 02070010 PL30, and encompasses 30,653 acres of mainly developed land in the Potomac River Basin. Accotink Creek flows into Gunston Cove, which is a tidal embayment of the Potomac River.

The land use characterization for the Accotink Creek watershed was based on the 2002 Fairfax County Land Use Dataset. Dominant land uses in the watershed are Medium Density Residential (25%), Open Space (19%) and Transportation (15%), which account for a combined 59% of the total land area in the watershed.

Environmental monitoring efforts in the Accotink Creek watershed include benthic community sampling and analysis, habitat condition assessments, ambient water quality sampling, sediment and fish tissue sampling, toxicity testing, and discharge monitoring. Monitoring efforts were conducted by the Virginia Department of Environmental Quality (DEQ), EPA, and the United States Geological Survey (USGS). Based on data obtained from DEQ at the time of TMDL development, there were five industrial facilities discharging stormwater pursuant to individual Virginia Pollutant Discharge Elimination

System (VPDES) permits, 16 industrial facilities discharging stormwater pursuant to a general VPDES permit, two concrete products facilities discharging stormwater pursuant to a general VPDES permit, six permits authorizing the discharge of stormwater from municipal separate storm sewer systems (MS4s), and 63 stormwater permits issued for construction activities within the Accotink Creek watershed.

Potential pollutant stressor(s) impacting the benthic macroinvertebrate community include nutrients (nitrogen and phosphorus), toxicity, metals and organic contaminants, and stormwater runoff and sedimentation. A stressor analysis determined that sedimentation caused by excessive stormwater runoff is the most probable stressor impacting the health of the benthic macroinvertebrate community.

Sediment and Flow Relationship

A sediment rating curve and a load duration curve were created for the Accotink Creek watershed to support the relationship between stormwater flow and sediment. The Accotink Creek sediment rating curve was developed using concurrently collected flow and sediment data at USGS and DEQ water quality monitoring stations. A total of 84 observations of sediment and flow, spanning the period from 1993 to 2007, were used to develop the rating curve. The sediment rating curve has an R^2 value of 0.756, indicating a direct relationship between sediment and stream flow. The load duration curve indicates that sediment loads increased significantly in the high-flow zone (i.e., the upper ten percent of all daily average flows). These curves illustrate the significant relationship between stream flow and sediment loads in Accotink Creek, and provide the basis for using flow as a surrogate for sediment in this TMDL. Efforts to reduce stormwater flow will decrease sediment loads, particularly in-stream sediment loads, which in turn will improve habitat conditions for the macroinvertebrate communities within the stream.

TMDL Endpoint Identification

The TMDL for Accotink Creek utilizes a "surrogate" approach in place of the traditional "pollutant of concern" approach to TMDL development. In this TMDL, reductions for a surrogate (stormwater runoff) are established to achieve the necessary reductions for the pollutant of concern (sediment). This TMDL uses a reference, or attainment, stream approach for developing the TMDL endpoint. Buffalo Creek and Catoctin Creek were selected as appropriate reference streams based upon analysis of DEQ monitoring data, USGS flow data, and the physical and hydrologic attributes of both watersheds. Under this approach, hydrologic targets for Accotink Creek are based on non-impaired stream flow data of Buffalo Creek and Catoctin Creek, where the aquatic life criteria are currently met as determined through DEQ benthic macroinvertebrate monitoring.

Flow duration curves (FDCs) were developed to identify appropriate hydrologic endpoints for this TMDL. FDCs depict the average percentage of time that specific daily average flows are equaled or exceeded at sites where continuous records of daily flow are available. FDCs are graphs, or tables, constructed from a set of flow measurements made over a given period of record, ranked from largest to smallest value, with the corresponding percentage of days for which the daily average flow value was equaled or exceeded during that period of record. A composite FDC was developed using the unimpaired watersheds of Buffalo Creek and Catoctin Creek in order to determine the conditions that need to be attained for Accotink Creek to meet aquatic life criteria.

The FDCs were developed using the daily average flow rates recorded at three USGS gage stations (one station located on Accotink Creek, and one station located on each of the selected attainment streams) during a 20-year period of record (November 1989-November 2009). The USGS daily average flow rates, expressed in cubic feet per second (cfs), were converted to cubic feet per day (ft^3/day) to address the need for final TMDL allocations to be expressed as daily loads. Additionally, since the three USGS stations drain different areas, the daily average flow rates (ft^3/day) were converted to daily average flow rates per unit-area (ft^3/acre-day) in order to develop FDCs that can be readily compared.

Because the urbanized nature of the Accotink Creek watershed generates greater rates of stormwater during precipitation events, the impaired Accotink FDC is higher than the non-impaired composite FDC at the high-flow range. Alternatively, the non-impaired composite FDC is higher at the low-flow range since the urbanized nature of the watershed decreases the amount of infiltration that occurs, resulting in less groundwater recharge and a decrease in stream baseflows.

To estimate the stormwater TMDL flow targets necessary for Accotink Creek to attain the aquatic life use, two design flow conditions were identified as appropriate hydrologic targets. A high-flow target value equal to the one-year, 24-hour flow rate and a low-flow target value equal to the 95th percentile flow rate were selected as points along the FDCs useful for setting specific hydrologic targets. The one-year, 24-hour storm flow rate is the maximum daily average flow rate with a one-year recurrence interval, while the 95th percentile flow represents a flow condition comparable to the lowest stream flow for seven consecutive days that would be expected to occur once in ten years (7Q10). Although both high and low-flow targets were established, TMDL allocations were based solely on the one-year, 24-hour high-flow target.

The TMDL target flow (i.e., the one-year, 24-hour stormwater flow) was estimated at 234 cfs using a 20-year flow record in Accotink Creek (November 1989-November 2009). The target flow of 234 cfs was then converted to a unit-area flow rate of 1,321.7 ft^3/acre-day, which falls within the high-flow portion of the Accotink FDC (0-10%). The one-year, 24-hour design flow in Accotink Creek of 1,321.7 ft^3/acre-day corresponds to a unit-area flow rate of 681.8 ft^3/acre-day on the composite attainment FDC. Therefore, 681.8 ft^3/acre-day is the TMDL target flow rate, and represents the maximum flow rate that Accotink Creek can receive during the one-year, 24-hour flow event without violating the stream's aquatic life criteria. Since this target flow rate was developed in terms of a unit-area flow rate (ft^3/acre-day) it will be applicable to the entire Accotink Creek drainage area.

TMDL Allocations

A TMDL establishes the amount of a pollutant that a waterbody can assimilate without exceeding its water quality standard for that pollutant. The TMDL for Accotink Creek was calculated using the following equation:

$$\text{TMDL} = \sum \text{WLA} + \sum \text{LA} + \text{MOS}$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

The MOS is a required component of the TMDL that accounts for any lack of knowledge concerning the relationship between the TMDL allocations and water quality. The MOS was implicitly incorporated into this TMDL by reducing uncertainty in the allocations and by incorporating a number of conservative assumptions into the development of the TMDL.

The LA for the Accotink Creek TMDL is based on the assumption that a portion of the existing stormwater flow in the Accotink Creek watershed is generated on lands that do not discharge to a regulated storm sewer system (i.e., lands that drain directly to the nearest receiving stream, or lands that drain to a privately owned/operated storm sewer system). Based upon the best professional judgment of EPA, DCR and an analysis of all available data, EPA conservatively estimates that 10% of the existing stormwater flow in the Accotink Creek watershed does not drain to a regulated storm sewer system. If, in the future, additional data becomes available which indicates that the percentage of stormwater flow from lands not connected to a regulated storm sewer system is higher or lower than 10%, the TMDL can be revised to reflect this information. Similarly, the WLA is based on the assumption that stormwater runoff from 90% of all land uses in the watershed drains to regulated storm sewer systems. Therefore, the existing stormwater flows from 90% of land uses were used to calculate the WLAs assigned to point sources. **Table E-1** summarizes the existing and allocated stormwater flows for the Accotink Creek Watershed.

Table E-1: Summary of Existing and Allocated Stormwater Flows

Source	Allocation Category	Acres	Existing Conditions (ft^3/acre-day)	Allocation (ft^3/acre-day)	Percent Reduction
Point Sources (WLA)	MS4 and Construction Stormwater Permits	26,601.5	1,150.7	594.4	48.3%
	Industrial Stormwater Permits	674.8	38.8	19.2	50.5%
	WLA Totals	**27,276.3**	**1,189.5**	**613.6**	**48.4%**
	Nonpoint Sources (LA)	**3,030.7**	**132.2**	**68.2**	**48.4%**
	TMDL Total	**30,307**	**1,321.7**	**681.8**	**48.4%**

The final recommended allocations for each source within the watershed are summarized in **Table E-2** and **Table E-3**. Overall, the magnitude of the one-year, 24-hour stormwater flow rate in the Accotink Creek watershed must be reduced by 48.4% in order to meet the established TMDL endpoint.

Table E-2: Stormwater TMDL for Accotink Creek (ft^3/acre-day)			
TMDL	**Load Allocation**	**Wasteload Allocation**	**Margin of Safety**
681.8	**68.2**	**613.6**	**Implicit**

Table E-3: Stormwater TMDL for Accotink Creek (Percent Reduction of the One-Year, 24-Hour flow)			
TMDL	**Load Allocation**	**Wasteload Allocation**	**Margin of Safety**
48.4%	**48.4%**	**48.4%**	**Implicit**

Expressing the TMDL on a Daily Basis

The Accotink Creek Stormwater TMDL implicitly expresses the allocations as daily loads. All of the allocations presented in this report are for a 24-hour period since the basis for developing the TMDL was the maximum daily average flow rate target that occurs once every year during a 24 hour period.

Margin of Safety

The CWA requires that a TMDL include a MOS to account for any lack of knowledge concerning the relationship between the TMDL allocations and water quality. The MOS may be implicit (i.e., built into the modeling process by using conservative modeling assumptions) or explicit (i.e., a percentage of the WLA, LA, or TMDL).

An implicit MOS has been incorporated into this TMDL by reducing uncertainty in the allocations and by incorporating a number of conservative assumptions in the development of the TMDL target and allocations. For example, by comparing Accotink Creek with multiple attainment streams in the Commonwealth of Virginia, uncertainty in the TMDL allocations was reduced. To limit the uncertainty associated with the use of any single reference watershed, flow data from Buffalo and Catoctin Creeks were used to develop a composite FDC for TMDL target-setting purposes. This composite FDC represents the average values of the flow data collected from two attainment streams, thus creating a more robust attainment FDC that accounts for a broader range of conditions, including eco-region, soils, slope, and land-use.

In addition, the TMDL target flow rate of 681.8 ft^3/acre-day represents a conservative value. According to the attainment stream approach, by definition, the flows for the attainment streams represent flows under which the Aquatic Life criteria are currently being met. It is reasonable to assume that the maximum flows in the attainment streams would allow Accotink Creek to comply with Virginia's water quality standards. However, EPA based the TMDL target on a composite FDC which was calculated based on the average value (as opposed to the maximum value) of the ranked unit-area flow rates in Buffalo Creek and Catoctin Creek. If the composite FDC had been developed using the maximum unit-area flow rates, the corresponding one-year, 24-hour target flow rate would have been higher than 681.8 ft^3/acre-day, and would have resulted in the establishment of a less conservative TMDL target. Thus, EPA's conservative use of the average unit-area flow rate instead of the maximum unit-area flow rate to establish the composite FDC and TMDL target provided an implicit MOS to the TMDL.

Finally, the use of attainment streams that are above the "threshold" of attainment represents another conservative assumption in the TMDL allocations. The Virginia Stream Condition Index (VSCI) scores for Buffalo Creek and Catoctin Creek consistently exceed the attainment threshold score of 60.0. Table 5-5 of the TMDL report provides a complete list of available VSCI scores for both Buffalo Creek and Catoctin Creek. The VCSI scores in Buffalo Creek range from 61.0 (Spring 2006) to 81.7 (Fall 2006), with an average score of 71.7, while the VSCI scores in Catoctin Creek range from 54.99 (Spring 2003) to 75.5 (Fall 1997), with an average score of 69.2. DEQ considers streams with a VSCI score between 60-72 to be in "good" condition. DEQ considers streams with a VSCI equal to or greater than 73 to be in "excellent" condition (VADEQ 2006). The average VSCI scores for both Buffalo Creek (71.7) and Catoctin Creek (69.2) fall within the "good" range, not the "excellent" range. As a result, the flow data from the attainment streams that was used to develop the composite FDC represent flows that are better than needed for attainment (without being overly protective), thus adding an additional implicit MOS to the TMDL.

Future Growth

EPA believes that new development and redevelopment provide the best opportunity to reduce stormwater flows. To meet the overall TMDL goal of a 48.4 percent reduction in the 1-year, 24-hour flow rate across the watershed, future permits authorizing new or expanded stormwater discharges within the Accotink Creek watershed must be consistent with the requirements and assumptions used to develop the WLAs in this TMDL.

Consideration of Seasonal Variability

The CWA requires that a TMDL be established with consideration of seasonal variations. The technical approach for this TMDL is based on the use of FDCs for defining hydrologic targets. The FDCs incorporate the complete spectrum of flow conditions, from very low to very high, that occur in the stream system over a period of 20 years. Therefore, the FDCs developed for this TMDL implicitly incorporate all seasonal flow variability.

Consideration of Critical Conditions

EPA regulations at 40 CFR 130.7(c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that designated uses are protected throughout the year, including times when waterbodies are most vulnerable. For the biological impairments in the Accotink Creek watershed, critical conditions occur during high-flow periods, when excessive stormwater runoff generates increased sediment loads from in-stream sources (e.g., bank erosion), causing habitat degradation for aquatic life (e.g., siltation, scour, over-widening of stream channel) and washout of biota. Critical conditions were inherently considered in the Accotink Creek stormwater TMDL by using a FDC approach with a one-year, 24-hour flow target. FDCs incorporate the full range of flow conditions from very low to very high, including the critical conditions that occur in the stream system over a long period of time (a 20-year period for the Accotink Creek TMDL). Additionally, use of the one-year, 24-hour flow as a TMDL endpoint, which is close to the upper end of the high-flow portion of the FDC, provides additional assurance that critical conditions are fully taken into account. Selecting a TMDL target close to the upper end of the FDC ensures that the implementation measures chosen to meet the target will also reduce the impact of the full range of storm events that drive the shape of the entire FDC.

Public Participation

Watershed stakeholders had opportunities to provide input and participated in the development of the TMDL during five TAC meetings and two public meetings.

1.0 Introduction

Section 303(d) of the Clean Water Act (CWA) and the United States Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (codified at Title 40 of the *Code of Federal Regulations* [CFR] Part 130) require Total Maximum Daily Loads (TMDLs) to be developed for impaired waterbodies. A TMDL establishes the amount of a pollutant that a waterbody can assimilate without exceeding its water quality standard for that pollutant. TMDLs provide the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of the state's water resources (USEPA, 1991).

A TMDL for a given pollutant and waterbody is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include an implicit or explicit margin of safety (MOS) to account for any uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. The TMDL components are illustrated using the following equation:

$$\text{TMDL} = \Sigma\, WLAs + \Sigma\, LAs + MOS$$

A lower portion of Accotink Creek, located in Fairfax County, Virginia, was first identified as impaired on Virginia's 1996 303(d) list for not meeting the aquatic life use due to poor health in the benthic biological community. In all subsequent 303(d) lists (1998, 2002, 2004, 2006, 2008), the benthic impairment for Accotink Creek has remained. In addition, an upper portion of Accotink Creek, located in Fairfax City, Virginia, was first identified as impaired on Virginia's 2008 303(d) list for not meeting the aquatic life use due to poor health in the benthic biological community (VADEQ, 2008a).

To address the aquatic life use impairments due to poor health in the benthic biological community, the causes of impairment were identified, and pollutant reductions were determined that will allow Accotink Creek to attain its designated uses. Section 1 of this report presents the regulatory guidance and defines the applicable water quality criteria for biological impairment. In Section 2 and Section 3, watershed and environmental monitoring data collected within the Accotink Creek watershed are presented and discussed. Stressors which may be impacting the creek are then analyzed in Section 4. Based on this analysis, potential stressors impacting benthic macroinvertebrate communities in the creek are identified. In Section 5 and Section 6, a TMDL is developed and presented for the stressor identified as the primary source of biological impairment in Accotink Creek.

1.1 Regulatory Framework

Section 303(d) of the CWA and the EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require TMDLs to be developed for waterbodies that are failing to meet State water quality standards. A TMDL establishes the amount of a pollutant that a waterbody can assimilate without exceeding its water quality standard for that pollutant. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and instream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollutant loadings from both point and nonpoint sources to restore and maintain the quality of their water resources (USEPA, 2001).

The primary environmental regulatory agency in the Commonwealth of Virginia is the Virginia Department of Environmental Quality (DEQ). DEQ works in coordination with the Virginia Department of Conservation and Recreation (DCR), the Virginia Department of Mines, Minerals, and Energy (DMME), and the Virginia Department of Health (VDH) to develop and implement a more effective TMDL process. As required by the CWA and Virginia's Water Quality Monitoring, Information and Restoration Act (WQMIRA), DEQ develops and maintains a listing of all impaired waters in the Commonwealth that details the pollutant(s) causing each impairment and the potential source(s) of each pollutant. This list is referred to as the Section 303(d) List of Impaired Waters.

A consent decree between EPA, the American Canoe Association, Inc., and the American Littoral Society requires the development of TMDLs for all impaired waters identified on Virginia's 1998 Section 303(d) list. Under the terms of the consent decree, EPA expected Virginia to complete these consent decree TMDLs by May 1, 2010. The Commonwealth failed to meet this deadline, therefore EPA must complete the remaining consent decree TMDLs by May 1, 2011. The biological impairment in Accotink Creek is among the list of consent decree waters identified on Virginia's 1998 Section 303(d) list, and the development of a TMDL to address this impairment was not completed by Virginia's May 1, 2010 deadline. EPA is therefore establishing this TMDL to meet this consent decree commitment.

1.2 Impairment Listing

A lower portion of Accotink Creek (TMDL Segment ID A15R-01-BEN) was first identified as impaired on Virginia's 1996 303(d) list for not meeting the aquatic life use due to poor health in the benthic biological community. The initial impairment extended from the confluence of Calamo Branch, downstream to the confluence with Pohick Creek in Gunston Cove (10.18 river miles). In the 2002 303(d) list, the length of the impaired segment was reduced to 8.62 river miles and included only the free-flowing waters of Accotink Creek. The length of the impairment was further reduced to 7.34 river miles on Virginia's 2008 303(d) list to reflect updated information regarding the head of tide.

On its 2008 303(d) list, Virginia identified an additional portion of Accotink Creek (A15R-04-BEN) as impaired for not meeting the aquatic life use due to poor health in the benthic biological community. This impairment extends from the confluence with an unnamed tributary to Accotink Creek, located in the upstream corridor of Ranger Park, and continues downstream until the confluence with Daniels Run (0.85 river miles). A complete 303(d) listing history for the Accotink Creek benthic impairments addressed in this TMDL report is provided in **Table 1-1**.

Table 1-1: Accotink Creek Benthic Impairment 303(d) Listing History			
Listing Year	**303(d) List ID**	**Impairment**	**Length**
1996	VAN-A15R	Benthic	10.18
1998	VAN-A15R*	Benthic	10.18
2002	VAN-A15R	General Standard (Benthic)	8.62
2004	VAN-A15R-01	General Standard (Benthic)	8.62
2006	00313	Benthic-Macroinvertebrate Bioassessments	8.62
2008	A15R-01-BEN	Benthic-Macroinvertebrate Bioassessments	7.34
2008	A15R-04-BEN	Benthic-Macroinvertebrate Bioassessments	0.85

* Consent Decree Water ID

In addition to the above mentioned benthic impairments, several segments of the free-flowing portion of Accotink Creek and a segment of Long Branch (stream code LOA) are also listed as impaired for not meeting the recreational use standard (exceedances of the *E. coli* bacteria criterion). The tidal portion of Accotink Creek is listed as impaired for not meeting the fish consumption use due to elevated levels of polychlorinated biphenyls (PCBs) in fish tissue. TMDLs have been completed for both the bacteria impairments (Upper Accotink, 2002; Lower Accotink, 2008) and the PCB impairment (Potomac PCB TMDL, 2007). Implementation of these bacteria and PCB TMDLs will not eliminate the benthic impairments in the Accotink Creek Watershed. A stressor identification analysis of the benthic impairments in Accotink Creek (Section 4) concluded that sedimentation caused by excessive stormwater runoff is the primary stressor impacting benthic invertebrates in the biologically impaired segments of the Accotink Creek watershed. Though TMDLs have been completed for bacteria and PCB impairments in the Accotink Creek watershed, EPA believes the implementation of these TMDLs, by themselves, will not eliminate the benthic impairments in Accotink Creek because they provide no assurance that the primary stressor to the benthic community (i.e., sedimentation caused by excessive stormwater runoff) will be reduced to the levels necessary to achieve compliance with water quality standards and attainment of the aquatic life designated use. **Figure 1-1** shows the benthic impairments addressed in this TMDL and the delineated watershed boundary for Accotink Creek.

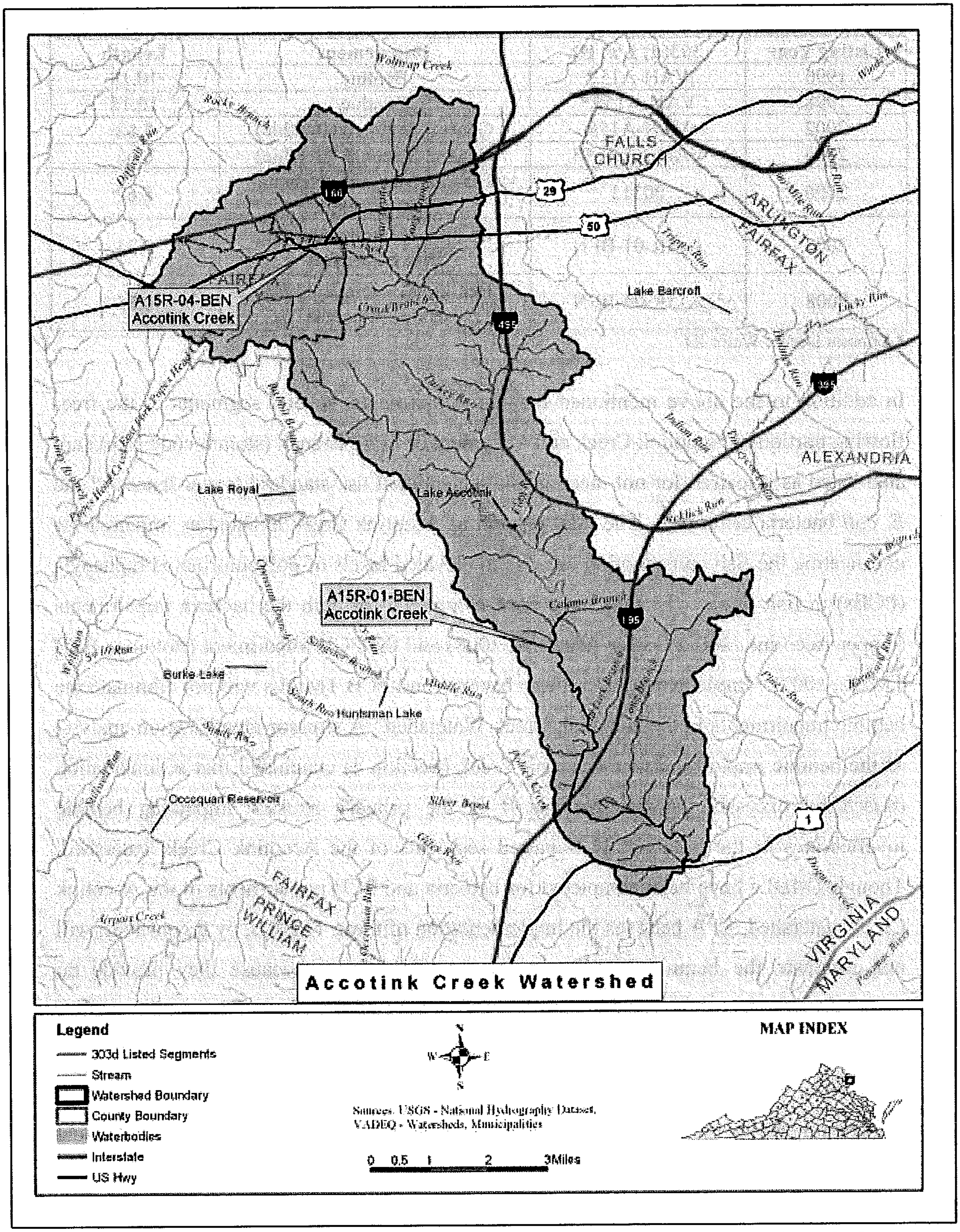

Figure 1-1: Accotink Creek Benthic Impaired Segments and Delineated Watershed

1.3 Applicable Water Quality Standard

Water quality standards include designated uses for a waterbody and water quality criteria necessary to support those designated uses. According to Virginia Water Quality Standards (9 VAC 25-260-5), the term *water quality standards* "means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect public health or welfare, enhance the quality of water, and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal CWA (33 USC §1251 et seq.)."

1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

> *"All state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

Based on the biological assessment surveys conducted on the stream, the listed segments of Accotink Creek defined in Section 1.2 do not support the propagation and growth of aquatic life.

1.3.2 Water Quality Criteria

The General Standard defined in Virginia Water Quality Standards (9 VAC 25-260-20) provides general, narrative criteria for the protection of designated uses from substances that may interfere with attainment of such uses. The General Standard states:

> *"All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life."*

The biological assessments conducted on Accotink Creek indicate that some pollutant(s) are interfering with attainment of the General Standard, as impaired macroinvertebrate communities have been observed in the listed segments of the stream.

2.0 Watershed Characterization

The physical conditions of Accotink Creek were characterized using a geographic information system (GIS) mapping database developed for the watershed. The purpose of the characterization was to provide an overview of the conditions in the watershed related to the benthic impairments present in the listed segments of the creek. Information contained in the watershed GIS database was used in the stressor identification analysis, as well as for subsequent TMDL development. In particular, physical watershed features such as topography, soil types, and land use conditions were characterized. In addition, the number and location of permitted discharge facilities and DEQ monitoring stations in the watershed were summarized.

2.1 Physical Characteristics

Physical characteristics of the Accotink Creek watershed that may be contributing to the benthic impairments were analyzed using GIS coverages developed for the area. GIS coverages for the watershed boundary, stream network, topography, soils, land use, and ecoregion of the watershed were compiled and analyzed.

2.1.1 Watershed Location and Boundary

The Accotink Creek watershed is located in Northern Virginia within portions of Fairfax County, the City of Fairfax and the Town of Vienna. The Accotink Creek watershed is located in hydrologic unit code (HUC) 02070010 PL30, and encompasses 30,653 acres of primarily developed land in the Potomac River Basin. Accotink Creek flows into Gunston Cove, which is a tidal embayment of the Potomac River.

2.1.2 Stream Network

The stream network for the Accotink Creek watershed was obtained from the United States Geological Survey (USGS) National Hydrography Dataset (NHD). The benthic impaired segments of the Accotink Creek watershed addressed in this TMDL Report, A15R-01-BEN and A15R-04-BEN, are 7.34 and 0.85 miles in length, respectively. The overall stream network and the benthic impaired segments are presented in **Figure 1-1**.

2.1.3 Topography

A digital elevation model (DEM) was used to characterize the topography in the watershed. DEM data obtained from USGS (10 meter resolution) indicate that elevation in the watershed ranges from approximately 7 to 492 feet above mean sea level, with an average elevation of 282 feet above mean sea level.

2.1.4 Soils

The Accotink Creek watershed soil characterization was based on data obtained from Fairfax County and the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database (Fairfax County, 2009; NRCS, 2006). There are 54 general soil associations located in the watershed (**Table 2-1**).

Table 2-1: Soil Associations within the Accotink Creek Watershed

Soil Association	Acres
Barker Crossroads - Nathalie complex	724.4
Barkers Crossroads - Rhodhiss complex	493.0
Barkers Crossroads loam	255.7
Barkers Crossroads-Rhodhiss-Rock Outcrop	0.9
Beltsville silt loam	399.3
Codorus and Hatboro soils	2,050.9
Codorus silt loam	610.7
Downer loamy sand	9.5
Elkton silt loam	29.2
Elsinboro loam	21.5
Fairfax loam	156.4
Glenelg silt loam	3,508.7
Grist Mill - Matapeake complex	19.3
Grist Mill - Mattapex complex	12.4
Grist Mill sandy loam	249.4
Gunston silt loam	110.6
Hatboro silt loam	317.5
Hattontown silt loam	2.3
Hattontown - Haymarket complex	4.8
Hattontown - Orange complex	8.1
Haymarket silt loam	2.8
Kingstowne - Beltsville complex	193.1
Kingstowne - Danripple complex	80.7

Table 2-1: Soil Associations within the Accotink Creek Watershed

Soil Association	Acres
Kingstowne - Sassafras - Marumsco complex	288.4
Kingstowne - Sassafras - Neabsco complex	1,115.4
Kingstowne - Sassafras complex	3.9
Kingstowne sandy clay loam	290.4
Lunt - Marumsco complex	115.7
Matapeake silt loam	43.0
Mattapex loam	127.4
Meadowville loam	340.3
Nathalie gravelly loam	293.0
Orange silt loam	22.7
Pits, gravel	5.8
Rhodhiss - Rock Outcrop complex	28.3
Rhodhiss sandy loam	504.5
Sassafras - Marumsco complex	1,013.4
Sassafras - Neabsco complex	120.5
Sassafras sandy loam	78.3
Sumerduck loam	219.2
Urban Land - Kingstowne complex	494.1
Urban Land	5,930.3
Urban Land - Barkers Crossroads complex	224.6
Urban Land - Grist Mill complex	65.0
Urban Land - Wheaton complex	955.0
Water	99.8
Whaton - Fairfax complex	656.4
Wheaton - Codorus complex	332.2
Wheaton - Glenelg complex	6,552.2
Wheaton - Hatboro complex	7.5
Wheaton - Meadowville complex	752.0
Wheaton - Sumerduck complex	233.6
Wheaton loam	363.9
Woodstown sandy loam	115.1
Total	**30,653**

Each soil association identified in **Table 2-1** is associated with a specific hydrologic soil group. Hydrologic soil groups are used to represent different levels of soil infiltration capacity. Hydrologic soil group "A" designates soils that are well to excessively well drained, whereas hydrologic soil group "D" designates soils that are poorly drained. This means that soils in hydrologic group "A" allow a larger portion of the rainfall to infiltrate and become part of the ground water system, whereas soils in hydrologic group "D" allow a smaller portion of the rainfall to infiltrate and become part of the ground water system. Consequently, more rainfall becomes part of the surface water runoff in hydrologic group "D" soils. The distribution of hydrologic soil groups in the Accotink Creek watershed is provided in **Table 2-2.** **Table 2-3** provides a brief description of each hydrologic soil group. A map of the hydrologic soil groups within the Accotink Creek watershed is shown in **Figure 2-1**.

Table 2-2: Hydrologic Soil Groups within the Accotink Creek Watershed

Hydrologic Soil Group	Acres	Percentage of Watershed
A	0.0	0%
B	3,793.0	12.4%
C	3,329.2	10.9%
D	21,860.8	71.3%
Blank*	1,670.0	5.4%
Total	**30,653.0**	**100.0%**

* Blank signifies portions of urban land, pits and water, which do not have soil hydrologic group associations

Table 2-3: Descriptions of Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	High infiltration rates. Soils are deep, well-drained to excessively-drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well-drained soils with moderately coarse textures.
C	Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
D	Very slow infiltration rates. Soils are clayey, have a high water table, or shallow to impervious cover.

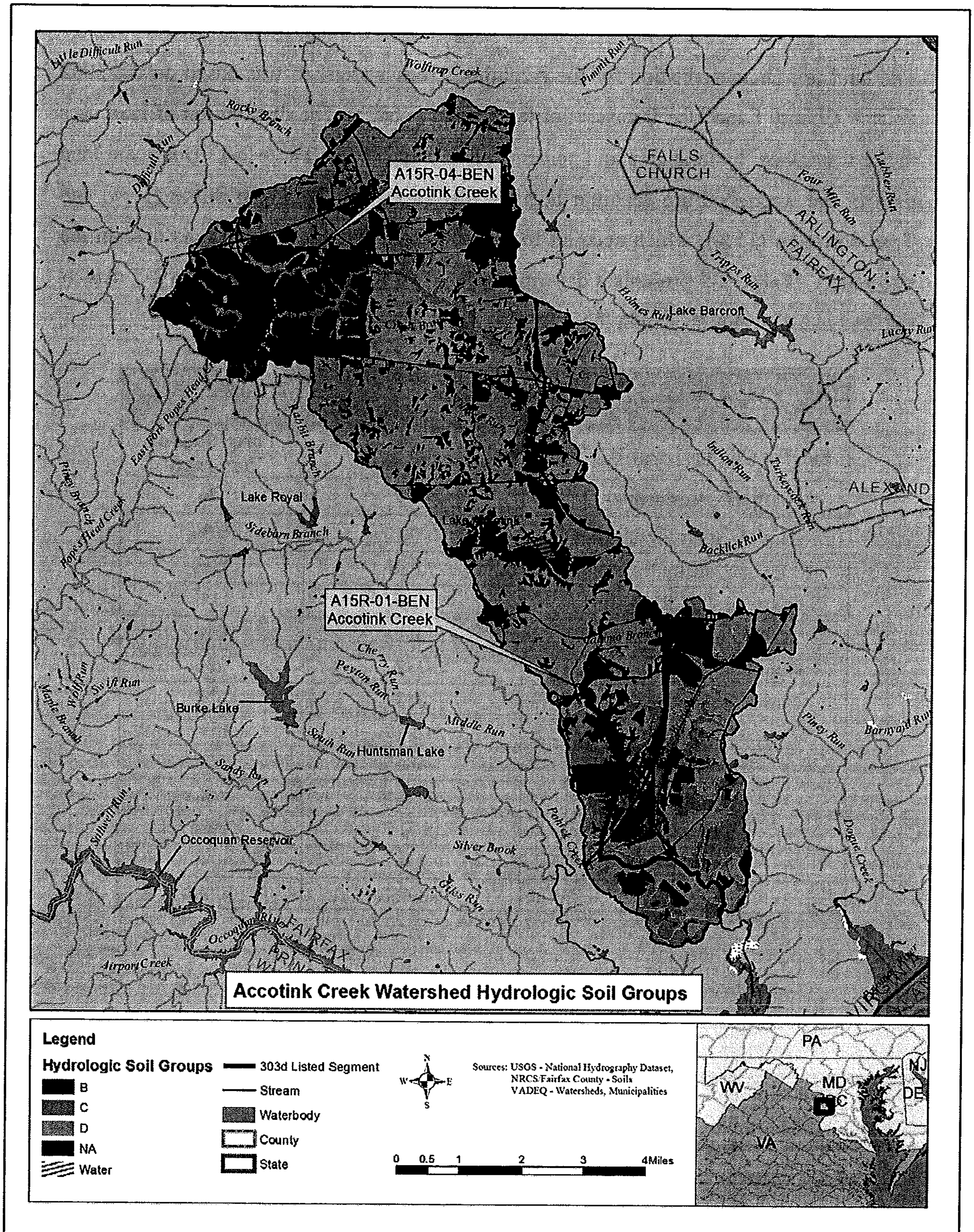

Figure 2-1: Hydrologic Soil Group Distribution in the Accotink Creek Watershed

2.1.5 Land Use

The land use characterization for the Accotink Creek watershed was based on the 2002 Fairfax County Land Use Dataset (Fairfax County, 2002). The distribution of land uses in the watershed, by land area and percentage, is presented in **Table 2-4**. Dominant land uses in the watershed are Medium Density Residential (25%), Open Space (19%) and Transportation (15%), which account for a combined 59% of the total land area in the watershed. **Table 2-5** presents a description for each land use type. **Figure 2-2** depicts the land use distribution within the Accotink Creek watershed.

Table 2-4: Land Use Categories within the Accotink Creek Watershed

Fairfax County Land-Use Type	Acres	Percentage of Watershed
Estate Residential	383	1%
High Density Residential	3,003	10%
Medium Density Residential	7,655	25%
Low Density Residential	3,286	11%
Industrial	1,949	6%
High Intensity Commercial	757	2%
Low Intensity Commercial	843	3%
Transportation	4,566	15%
Golf Course	686	2%
Institutional	1,464	5%
Open Space	5,715	19%
Water	346	1%
Total	**30,653**	**100%**

Table 2-5: Descriptions of Land Use Types

Land Use Type	Description
Estate Residential	Single-family detached homes with more than two acres per residence
High Density Residential	Single-family and multifamily residential with more than eight dwelling units per acre
Medium Density Residential	Single-family detached homes with less than 0.5 acres per residence and attached multifamily residential with fewer than eight dwelling units per acre
Low Density Residential	Single-family detached homes with 0.5 to 2 acres per residence
Industrial	Industrial land use and industrial parks
High Intensity Commercial	Highly impervious commercial and office uses, including office complexes, shopping centers, strip malls, automobile dealerships and restaurants
Low Intensity Commercial	Office parks and commercial facilities developed in a campus-like setting. Also includes private recreational facilities such as swim clubs, tennis clubs, and buildings and parking associated with golf courses and parkland
Transportation	Transportation land use
Golf Course	Open space associated with golf courses
Institutional	Facilities open to the public, including churches, schools, libraries, and county office buildings
Open Space	Parkland, privately owned open space, and vacant developable land. Extensive parking areas or buildings associated with parkland are included as low intensity commercial.
Water	Open water, lakes and ponds
Source: Fairfax County Department of Public Works and Environmental Services	

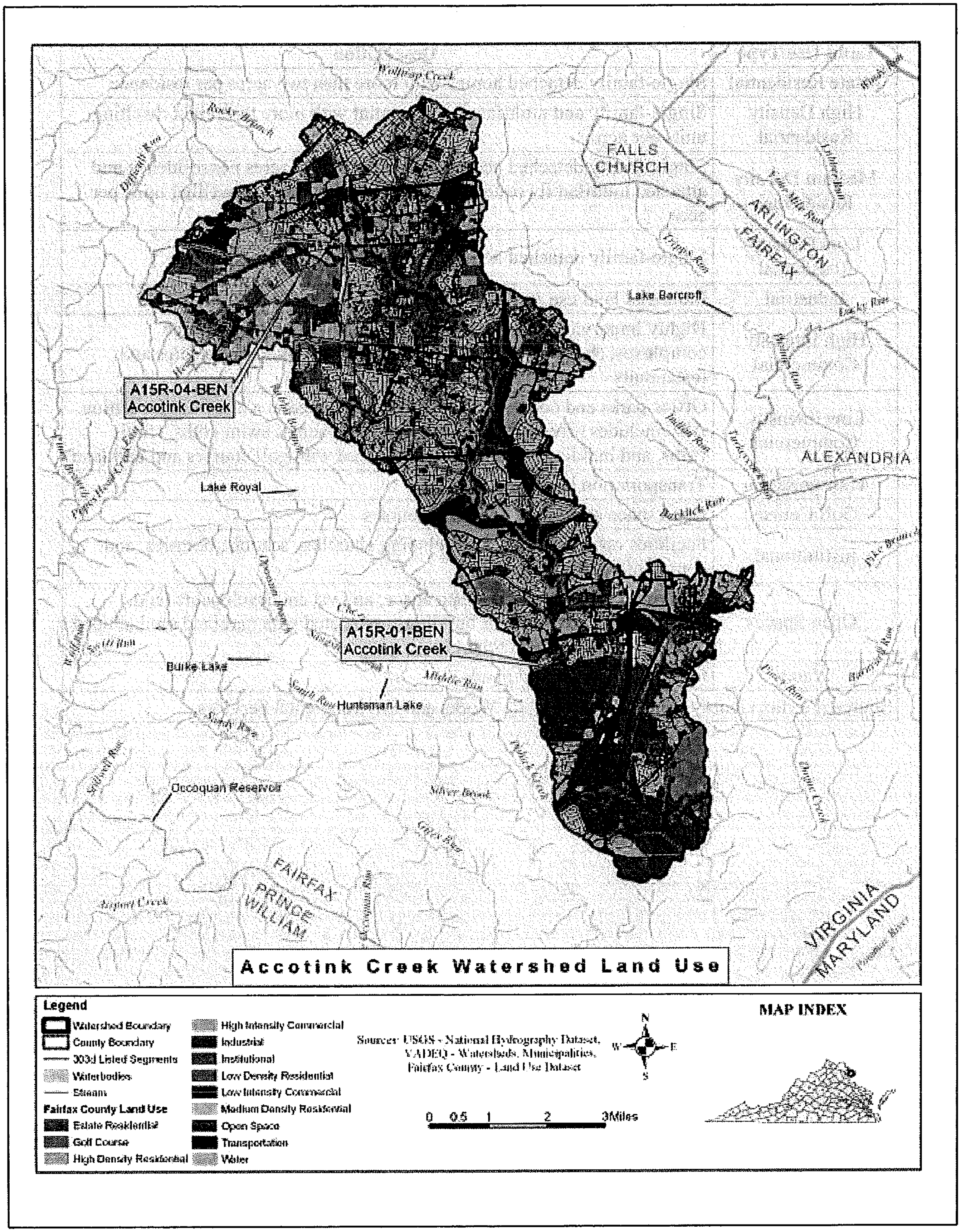

Figure 2-2: Land Use in the Accotink Creek Watershed

2.1.6 Ecoregion Classification

The Accotink Creek watershed is located in the Northern Piedmont, Piedmont, and Southeastern Plains ecoregions, EPA Level III classification numbers 64, 45, and 65, respectively (Woods et al., 1996). The location of the Accotink Creek watershed within these ecoregions is presented in **Figure 2-3**; the majority of the watershed is situated within the Piedmont ecoregion.

The Piedmont ecoregion extends from Wayne County, Pennsylvania, southwest through Virginia, and comprises a transitional area between the mostly mountainous ecoregions of the Appalachians to the northwest and the flat coastal plain to the southeast. Once largely cultivated, much of this region has reverted to pine and hardwood woodlands. The Piedmont ecoregion is characterized by shallow valleys, irregular plains, and low rounded hills and ridges. The underlying geology of this region consists of deeply weathered, deformed metamorphic rocks with intrusions by igneous material.

The Northern Piedmont ecoregion extends from New Jersey down through northern Virginia and is characterized by low, rounded hills, irregular plains, and open valleys. The Northern Piedmont is a transition zone between the coastal areas to the east and the more mountainous areas to the north and west. The underlying geology of this region consists of a mix of metamorphic, igneous, and sedimentary rocks.

The Southeastern Plains ecoregion extends from Maryland down into Louisiana and is characterized by irregular, relatively flat plains. Natural forests of oak, hickory, and pine once dominated the ecoregion, but have been largely replaced by heavily managed timberlands. The underlying geology is younger than that of the Piedmont, consisting of more recent sands, silts, and clays.

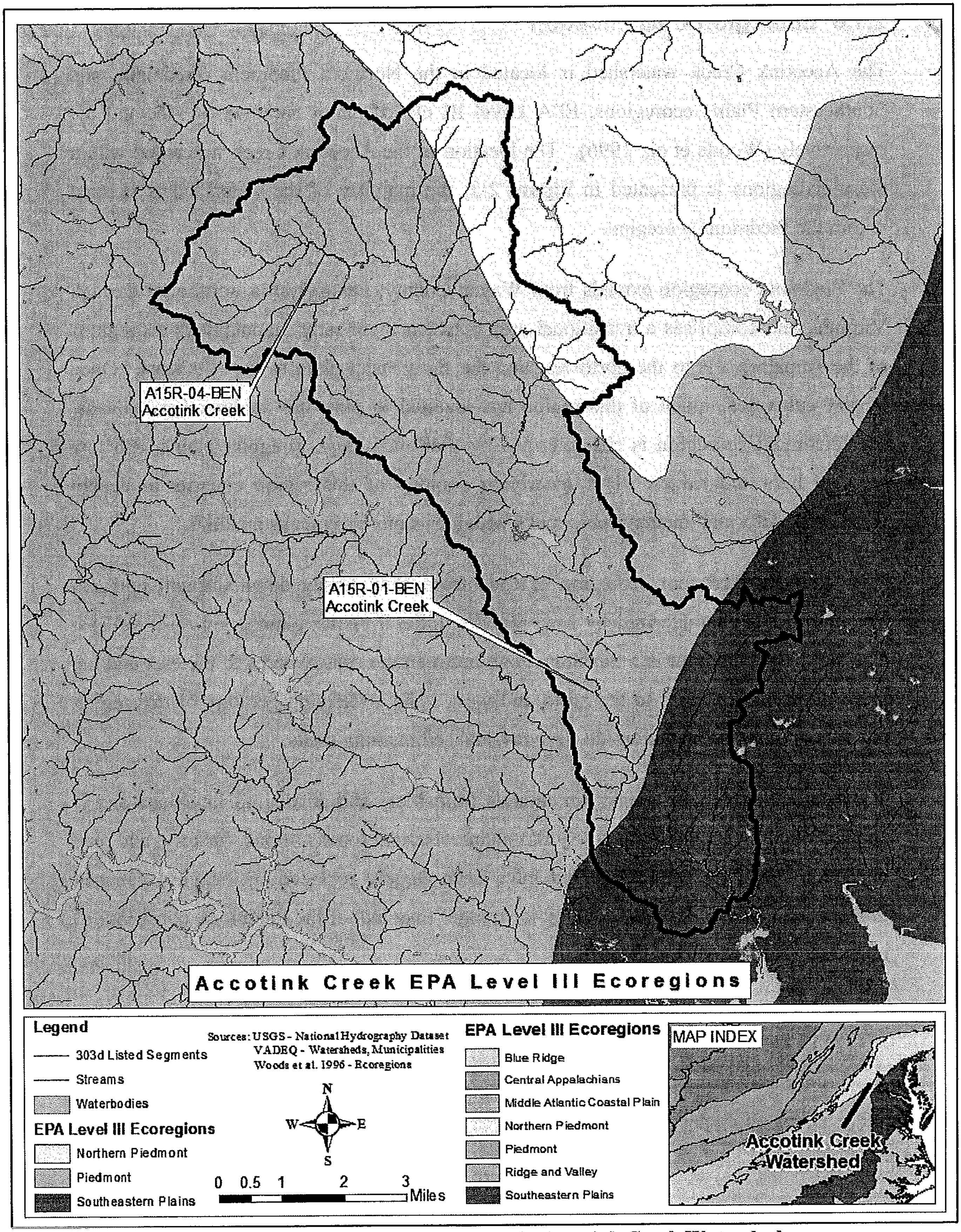

Figure 2-3: EPA Level III Ecoregions in Accotink Creek Watershed

2.2 Permitted Discharge Facilities

Data obtained from the DEQ's Northern Regional Office indicate there are five industrial facilities currently holding individual Virginia Pollutant Discharge Elimination System (VPDES) permits that authorize discharges of stormwater runoff within the Accotink Creek Watershed. The permit number, classification, and category for each of these permits are presented in **Table 2-6**. The location of each permit is shown in **Figure 2-4.**

Table 2-6: Individual Permits Authorizing Discharges of Stormwater Associated with Industrial Activity in the Accotink Creek Watershed

Permit No	Facility Name	Receiving Stream	Classification	Category
VA0001988	Motiva Enterprises LLC - Springfield	Accotink Creek, UT	Minor	Industrial
VA0057380	Quarles Petroleum - Newington	Accotink Creek, UT	Minor	Industrial
VA0001945	Kinder Morgan Southeast Terminals LLC - Newington	Accotink Creek, UT	Minor	Industrial
VA0001872	Fairfax Terminal Complex	Daniels Run, UT	Minor	Industrial
VA0002283	Motiva Enterprises LLC - Fairfax	Crook Branch	Minor	Industrial

In addition to individual VPDES stormwater permits, there are also two concrete products facilities and 16 industrial facilities discharging stormwater pursuant to general VPDES permits in the Accotink Creek watershed. These facilities are identified in **Table 2-7**, and are mapped in **Figure 2-4**.

Table 2-7: General Permits issued to Concrete Products Facilities and Discharges of Storm Water Associated With Industrial Activity in the Accotink Creek Watershed.

Permit Type	Permit No	Facility Name	Receiving Stream
Concrete	VAG110046	Newington Concrete Corporation - 8413 Terminal Rd	Accotink Creek, UT
	VAG110069	Virginia Concrete Company Inc - Newington Plant 2	Long Branch
Industrial Stormwater	VAR050988	Canada Dry - Springfield	Accotink Creek
	VAR051042	SICPA Securink Corporation	Accotink Creek
	VAR051047	Fairfax County - Connector Bus Yard	Long Branch
	VAR051053	United Parcel Service - Springfield	Flag Run
	VAR051066	US Postal Service - Merrifield Vehicle Maintenance	Long Branch, UT
	VAR051100	Shenandoahs Pride Dairy	Flag Run
	VAR051109	Federal Express Corporation - NYGA Station former	Lake Accotink
	VAR051771	Fairfax County - Newington Maintenance Facility	Long Branch
	VAR051134	G and L Metals	Long Branch, UT
	VAR051565	Rolling Frito Lay Sales LP - South Potomac DC	Accotink Creek
	VAR051770	Fairfax County - Jermantown Maintenance Facility	Accotink Creek
	VAR051719	National Asphalt Paving Corporation – Fairfax	Accotink Creek
	VAR051772	Fairfax County - DVS - Alban Maintenance Facility	Field Lark Branch
	VAR051795	HD Supply - White Cap	Accotink Creek
	VAR051863	United Parcel Service - Newington	Accotink Creek
	VAR051080	Fort Belvoir Davison Army Airfield (DAAF)	Accotink Creek

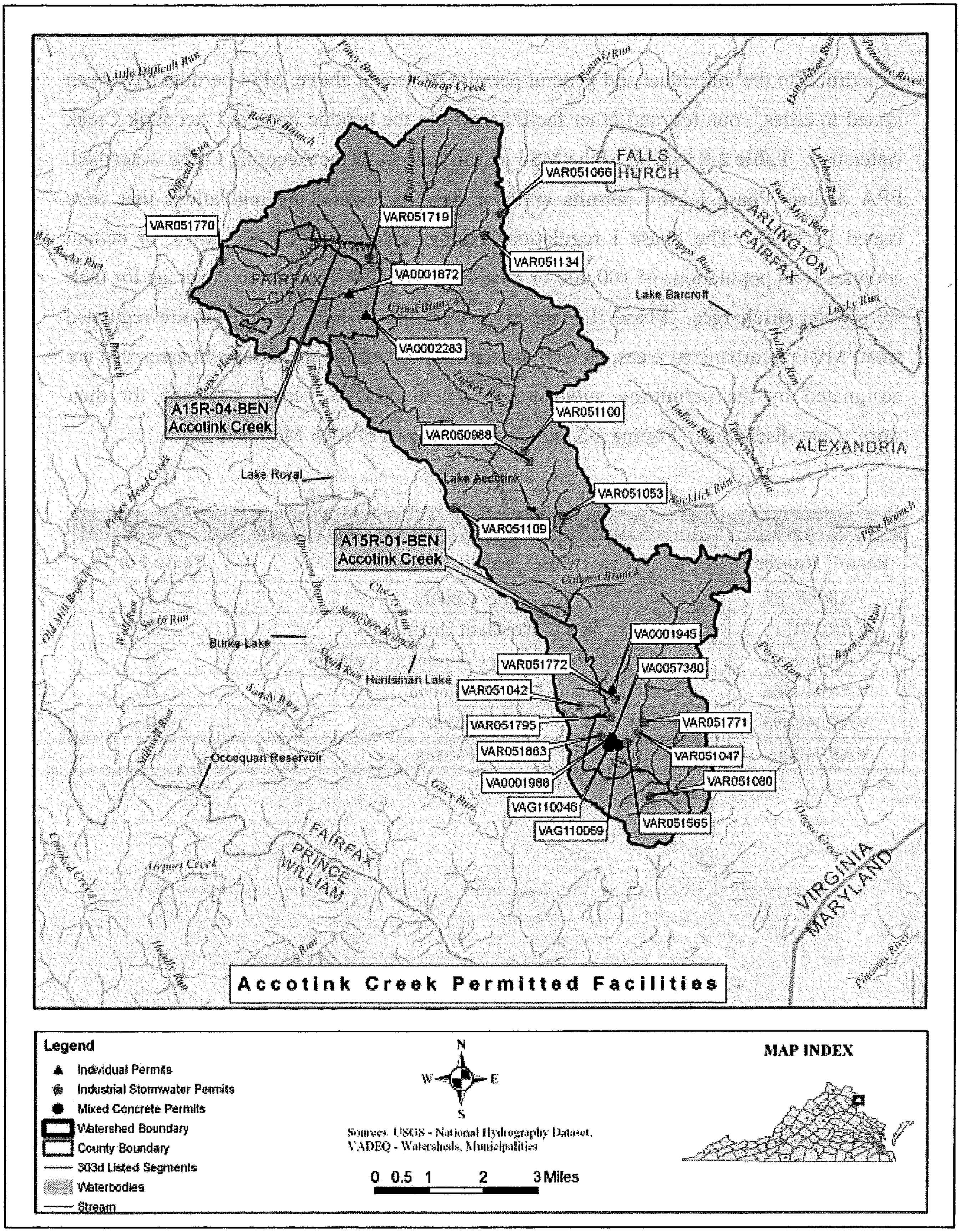

Figure 2-4: Location of Permitted Facilities in the Accotink Creek Watershed

2.3 Municipal Separate Storm Sewer System (MS4) Permits

In addition to the individual and general permits presented above, MS4 permits have been issued to cities, counties, and other facilities within the benthic impaired Accotink Creek watershed. **Table 2-8** lists all of the MS4 permit holders in the Accotink Creek watershed. EPA defines Phase I MS4 permits as those permits covered by regulations that were issued in 1990. The Phase I regulations require medium and large cities, or certain counties with populations of 100,000 or more, to obtain NPDES permit coverage for their stormwater discharges. Phase II regulations were issued in 1999 and require regulated small MS4s in urbanized areas, as well as small MS4s outside the urbanized areas that are designated by the permitting authority, to obtain NPDES permit coverage for their stormwater discharges. **Figure 2-5** depicts the locations of each MS4 area.

Table 2-8: MS4 Permits within the Accotink Creek Watershed

Permit Number	MS4 Permit Holder	Phase I or II
VA0088587	Fairfax County	I
VAR040115	VDOT Northern Urban Area	II
VAR040095	Northern Virginia Community College	II
VAR040066	Town of Vienna	II
VAR040093	Fort Belvoir	II
VAR040064	City of Fairfax	II

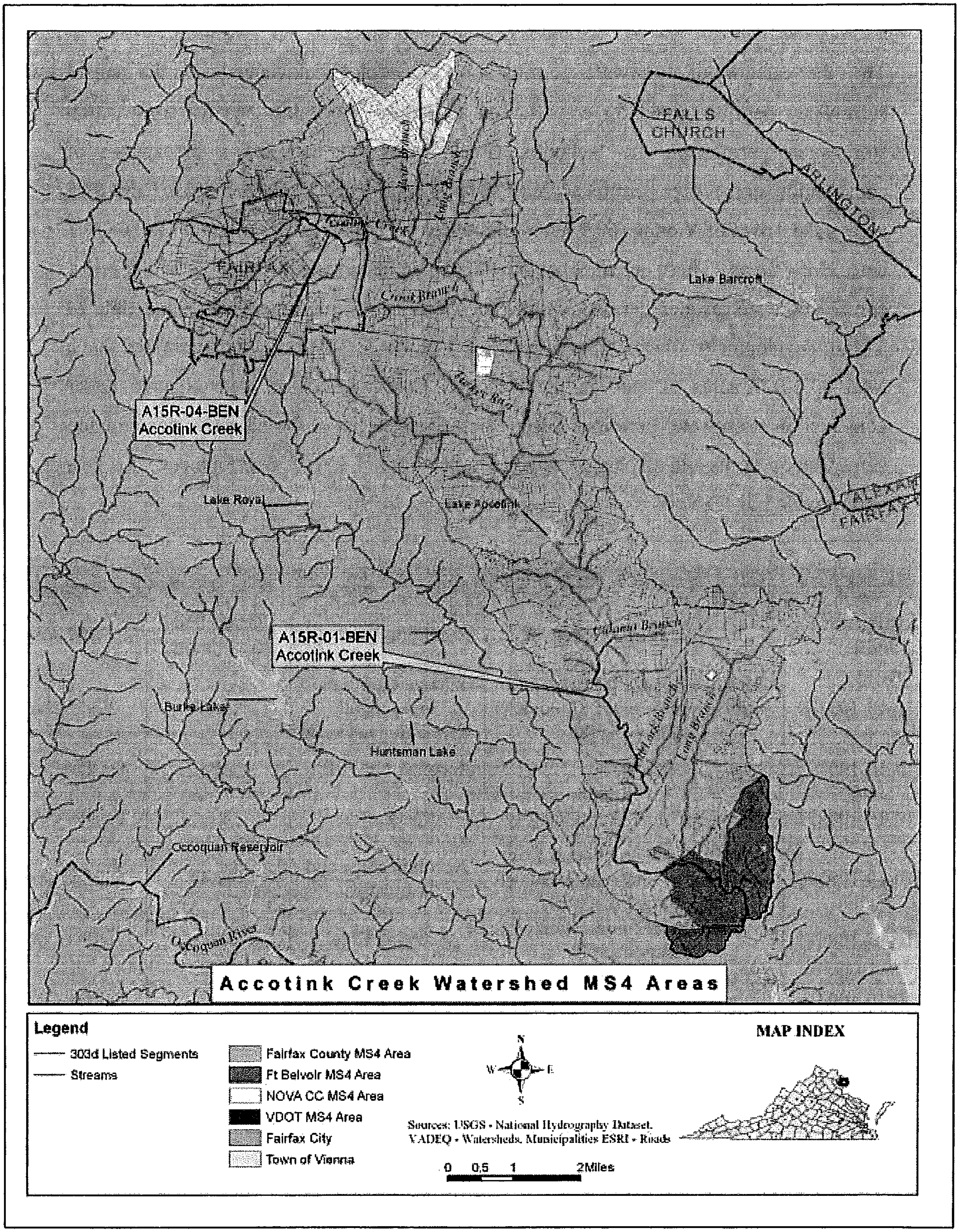

Figure 2-5: Locations of each MS4 area in the Accotink Creek Watershed

2.4 Construction Stormwater Permits

The other category of stormwater permits in the Accotink Creek watershed is the general stormwater permits issued for construction activities. Available data for construction stormwater permits in the Accotink Creek watershed included a breakdown of construction stormwater permits within Fairfax County (412.3 acres), Fairfax City (83.8 acres), the Town of Vienna (60.9 acres), Fort Belvoir (440.5 acres) and the VDOT (79.7 acres) MS4 areas. These acreages are based upon an instantaneous snapshot of the active construction stormwater permits within the Accotink Creek watershed at the time of TMDL development. Based on this snapshot (October 5, 2010), it was determined that a total of 1,077 acres of land in the Accotink Creek watershed were covered under construction stormwater permits. **Table 2-9** provides a list of the 63 active construction stormwater permits and associated acreages at the time of TMDL development. This data was provided by DCR.

Table 2-9: Construction Projects as of October 2010 in the Accotink Creek Watershed

VAR Permit Number	Nature of Project	Receiving Water(s)	Disturbed Area (acres)	MS4 Area
VAR10-10-103330	Utilities/Roads - roadway and utility improvements to Pohick Rd/Belvoir Rd	unnamed tributaries to Accotink Creek/Dogue Creek	14.07	Fort Belvoir
VAR10-10-100155	Industrial	Accotink Creek/Bay	18.5	Fairfax County
VAR10-10-100257	Commercial child care facility	Mason Run	3.6	Fairfax County
VAR10-10-100396	Industrial construction of FCP and improvements to existing access roads network	Accotink creek and tributaries	135.34	Fairfax County
VAR10-10-100414	Commercial construction of storage facility	Accotink Creek	0.8	Fairfax County
VAR10-10-100415	Commercial construction of infrastructure: roadways, power substation and sanitary sewage	Accotink Creek	34	Fairfax County
VAR10-10-100831	Residential construction	Unnamed tributary of Accotink Creek	4.29	Fairfax County
VAR10-10-100840	Industrial construction of interstate	Scott Run- Pimmit Run - Holmes Run - Accotink Creek - Backlick Run - Potomac River	83	Fairfax County
VAR10-10-100918	Residential construction	Accotink Creek	0.6	Fairfax City

Table 2-9: Construction Projects as of October 2010 in the Accotink Creek Watershed

VAR Permit Number	Nature of Project	Receiving Water(s)	Disturbed Area (acres)	MS4 Area
VAR10-10-101030	Commercial construction of Golf Club	Accotink Creek	5	Fairfax County
VAR10-10-101324	Residential construction of elderly living facility	Accotink Creek	4.55	Fairfax County
VAR10-10-101330	Military recreational facility and golf course renovations	Daniels Run and Accotink Creek	73.4	Fairfax City
VAR10-10-101516	Municipal construction of public library	Accotink Creek	1.5	Fairfax County
VAR10-10-101587	Commercial site plan addition	Accotink Creek	1.8	Fairfax County
VAR10-10-102375	Commercial construction	Unnamed tributary to Accotink Creek	4.76	Fairfax City
VAR10-10-102384	Public Building & Associated Site Amenities	Accotink Creek	0.9	Fairfax City
VAR10-10-102443	Commercial construction of religious facility	Backlick Run	3.4	Fairfax County
VAR10-10-102448	Residential construction of single-family dwellings	Accotink Creek	1	Fairfax City
VAR10-10-102546	Roadway Improvement	Long Branch	4.86	Fairfax County
VAR10-10-102551	Residential construction	Unnamed tributary to Accotink Creek	5.7	Fairfax County
VAR10-10-102718	Commercial construction	Central Fork Accotink Creek	1.3	Fairfax County
VAR10-10-102759	Commercial	Unnamed tributary to Daniels Run	1.72	Fairfax City
VAR10-10-102801	Recreational	unnamed tributary to Accotink Creek	1.06	Fairfax County
VAR10-10-102856	Educational/Recreational - replacement of synthetic turf field	Accotink Creek	4.01	Fairfax County
VAR10-10-102859	Residential	Unnamed tributary to Accotink Creek	1.42	Fairfax City
VAR10-10-102950	Residential	Daniels Run	0.04	Fairfax City
VAR10-10-102992	Commercial	Accotink Creek	3	Fairfax County
VAR10-10-103339	Commercial - Office	County of Fairfax	2.86	Fairfax County
VAR10-10-103492	Single Family Residence	Accotink Creek	3.9	Fairfax County
VAR10-10-103496	Roadway construction - Removal of existing roadway and concrete	Accotink Creek	0.98	Fairfax County
VAR10-10-103719	Residential - single family	Accotink Creek	10.2	Fairfax County
VAR10-10-103725	Commercial -Office Building,	Long Branch	3.4	Fairfax County

Table 2-9: Construction Projects as of October 2010 in the Accotink Creek Watershed

VAR Permit Number	Nature of Project	Receiving Water(s)	Disturbed Area (acres)	MS4 Area
	parking garage and associated infrastructure			
VAR10-10-103967	Institutional - Church (a place of worship)	Accotink Creek a tributary of the Potomac River	2	Fairfax County
VAR10-10-103969	Utility - Electric Transmission Line	South Run, Sangster Branch, Peyton Run, Pohick Creek, Accotink Creek	11.09	Fairfax County
VAR10-10-103990	Utility - Underground utility watermain installation	Unnamed tributaries to Accotink Creek	4.5	Fairfax County
VAR10-10-103991	Military - Construction of paved vehicle inspection area for base	Unnamed tributaries to Accotink Creek	6.7	Fairfax County
VAR10-10-100066	Commercial - Military	Potomac	9	Fort Belvoir
VAR10-10-100401	Commercial construction	Potomac River	5	Fort Belvoir
VAR10-10-100445	Commercial construction of government office facility	Accotink Creek	237	Fort Belvoir
VAR10-10-100619	Commercial construction of federal emergency service center	Accotink Creek	6.05	Fort Belvoir
VAR10-10-101592	Residential army family housing and roadway improvements	Unnamed tributary to Gunston Cove	18.8	Fort Belvoir
VAR10-10-102402	Commercial construction	Dogue Creek - Accotink Creek - Accotink Bay	68.3	Fort Belvoir
VAR10-10-102459	Commercial	Gunston Cove	3.3	Fort Belvoir
VAR10-10-103018	building addition	unnamed tributary to Potomac Rv	0.02	Fort Belvoir
VAR10-10-103356	Utilities - electrical duct bank/manhole installation	Potomac Rv	1.64	Fort Belvoir
VAR10-10-103546	US Army runway electrical improvements	Unnamed tributary of Gunston Cove - Potomac River	1.9	Fort Belvoir
VAR10-10-103908	Environmental - Shoreline Improvement : removing existing bulkheads, regrading upland areas	Gunston Cove to Potomac River	0.21	Fort Belvoir
VAR10-10-104073	Child Care facility on an Army military installation	Mason Run	3.6	Fort Belvoir
VAR10-10-100248	Construction and design of elementary school	Accotink Creek	1.7	Vienna
VAR10-10-100917	Residential construction	Accotink Creek Watershed	0.9	Vienna
VAR10-10-102119	Residential construction	Accotink Creek	58.28	Vienna
VAR10-10-102917	Pedestrian Improvement	Accotink Creek	0.02	Vienna

Table 2-9: Construction Projects as of October 2010 in the Accotink Creek Watershed

VAR Permit Number	Nature of Project	Receiving Water(s)	Disturbed Area (acres)	MS4 Area
VAR10-10-102918	Pedestrian Improvement	Accotink Creek	0.01	Vienna
VAR10-10-104911	Merrifield Town Center - Infrastructure Improvements	Long Branch to Accotink Creek	35.71	Fairfax County
VAR10-10-104908	Fort Belvoir - Main Post Phase II- Road and Utility Improvements	Mason Run and unnamed tributaries to Mason Run, Accotink Bay, and Accotink Creek	53.31	Fort Belvoir
VAR10-10-104800	Pine Ridge Park - Public Facility	Accotink Creek	3.29	Fairfax County
VAR10-10-104727	Pine Ridge Sanitary Sewer E&I; Fairfax County Project #X00828 (10007) - Public Sanitary Sewer Extension to Connect Existing Homes to Public Sewer	Accotink Creek	0.95	Fairfax County
VAR10-10-104648	Franconia Elementary Schools - Public School	Cameron Run, Accotink Ck, Douge Ck	4.1	Fairfax County
VAR10-10-104551	Marriott Residence Inn - Hotel	Accotink Creek	2.96	Fairfax County
VAR10-10-104383	Bannerwood Estates - Residential	Accotink Creek	3.9	Fairfax County
VAR10-10-104340	Fort Belvoir Warriors In Transition (WIT) Complex - Construction of Two Office Buildings & Two Barracks - Commercial	Unnamed tributary to Accotink Bay	18.3	Fort Belvoir
VDOT Projects	0095-96A-104,c501 10.9.7.03		79.5	Fairfax County
	0050-96A-353 10.9.1.11		0.2	Fairfax County
		Total	**1077.2**	

3.0 Environmental Monitoring

Environmental monitoring efforts in the Accotink Creek watershed include benthic community sampling and analysis, habitat condition assessments, ambient water quality sampling, sediment and fish tissue sampling, toxicity testing, and discharger monitoring. Monitoring efforts presented in this chapter were conducted by DEQ, EPA, and USGS. **Figure 3-1** depicts the locations of the monitoring stations that were used in the analysis of the benthic impairments in Accotink Creek.

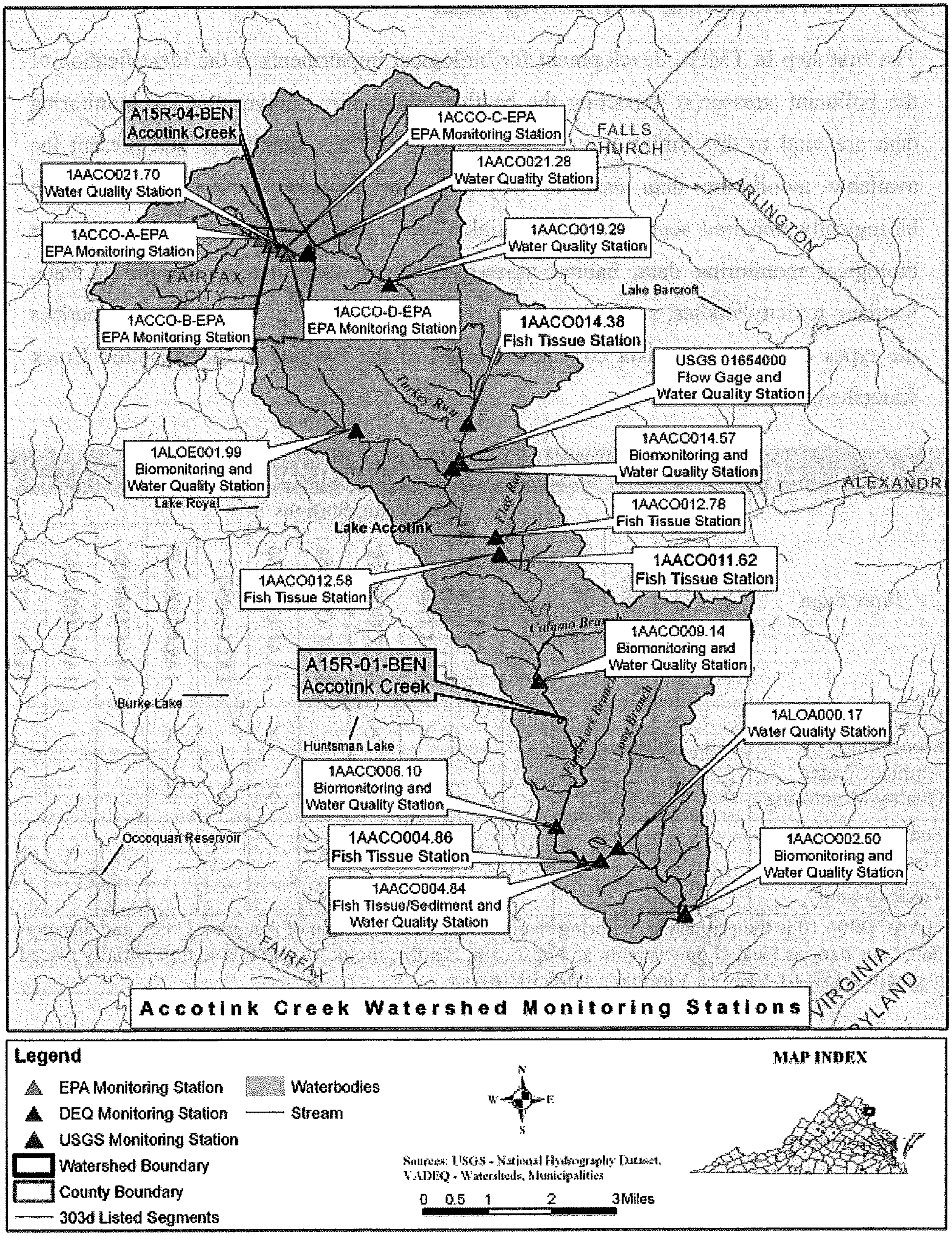

Figure 3-1: Monitoring Locations in the Accotink Creek Watershed

3.1 Environmental Monitoring Data

The first step in TMDL development for biological impairments is the identification of the pollutant stressor(s) impacting the benthic community. Environmental monitoring data are vital to this initial step. The following sections summarize and present the available monitoring data used to determine the primary stressor impacting the biologically impaired segments of Accotink Creek. Data analyzed included available biological monitoring data, habitat assessment data, water quality monitoring data, instream toxicity studies, and sediment and fish tissue sampling. **Table 3-1** summarizes the types of monitoring data collected at each of the stations in the Accotink Creek watershed.

Table 3-1: Inventory of DEQ Environmental Monitoring Data for Accotink Creek

Data Type	Monitoring Stations														
	1AACO021.70	1AACO021.28	1AACO019.29	1AACO014.57	1AACO012.78	1AACO012.58	1AACO009.14	1AACO006.10[1]	1AACO004.84	1AACO002.50	1ALOA000.17	1ALOE001.99	1AACO004.86	1AACO011.62	1AACO014.38
Biological Monitoring				X			X	X		X		X			
Ambient Water Quality Monitoring	X	X	X	X			X	X	X	X	X	X			
Sediment and Fish Tissue Sampling					X	X			X				X	X	X
Toxicity Study								X	X						

[1]1AACO006.10 is the primary monitoring station in the lower portion of Accotink Creek and has more data than stations located downstream and upstream. Benthic monitoring at this station initially placed segment A15R-01-BEN on Virginia's 1996 303(d) list.

3.1.1 Biological Monitoring Data

Based on biological monitoring data, Accotink Creek (TMDL Segment ID A15R-01-BEN) was originally listed as impaired on the 1996 303(d) list for not meeting the aquatic life use due to poor health in the benthic biological community. Accotink Creek was subsequently listed in the 1998, 2002, 2004, 2006, and 2008 Integrated 305(b)/303(d) Assessments, as indicated in **Table 1-1**. Biological monitoring data were collected at station 1AACO006.10 from 1994 to 1996 and again from 2006 to 2008. Additional biological monitoring data were collected at station 1ALOE001.99 in 2006, station 1AACO002.50 in 2006 and 2007, station 1AACO0014.57 in 2007, and station 1AACO009.14 in 2008.

Biological monitoring data was evaluated using the Virginia Stream Condition Index (VSCI). Calculation of a VSCI score incorporates eight standard metrics, based on the abundance and types of macroinvertebrates present at each station. The multiple metrics evaluated together give an overall indication of ecological integrity. These bioassessment scores were compared to a reference condition, which is based on an aggregate of unimpaired streams in non-coastal Virginia. The VSCI metrics and their expected response to declining stream conditions are presented in **Table 3-2**. An impairment cutoff score of 60.0 is used for assessing results. Stream segments that have a VSCI score of 60 or greater are generally considered to be non-impaired, while streams that score less than 60 are generally considered impaired (VADEQ, 2010).

Table 3-2: Metrics Used to Calculate the Virginia Stream Condition Index (VSCI)

Metrics	Expected Response to Disturbance	Definition of Metric
Taxonomic Richness		
Total Taxa	Decrease	Total number of Taxa observed
EPT Taxa	Decrease	Total number of pollution sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa observed
Taxonomic Composition		
% EPT Less Hydropsychidae	Decrease	% EPT taxa in samples, subtracting pollution-tolerant Hydropsychidae
% Ephemeroptera	Decrease	% Ephemeroptera taxa present in sample
% Chironomidae	Increase	% pollution-tolerant Chironomidae present
Balance/Diversity		
% Top 2 Dominant	Increase	% dominance of the 2 most abundant taxa
Tolerance		
MHBI (Family level)	Increase	Modified Hilsenhoff Biotic Index (MHBI)
Trophic Group		
% Scrapers	Decrease	% of scraper functional feeding group

VSCI Scores

In the Accotink Creek watershed, VSCI scores were calculated for stations 1AACO002.50, 1AACO006.10, 1AACO009.14, 1AACO0014.57, and 1ALOE001.99. Stations 1AACO002.50, 1AACO006.10 and 1AACO009.14 are located on the lower impaired segment of Accotink Creek, while stations 1AACO0014.57 and 1ALOE001.99 are located upstream of the lower impaired segment of Accotink Creek (**Figure 3-1**). The following is a summary of the metrics used in calculating the VSCI scores.

a) Taxonomic Richness

Taxa richness measures the overall variety of the invertebrate assemblage by counting the number of distinct taxa within selected taxonomic groups (Burton et al. 2003). High taxa richness is usually an indicator of a healthy benthic community. At the Accotink Creek watershed monitoring stations, the average total taxa ranged from 7.5 to 11.2 and averaged 9.6 distinct taxa (**Figure 3-2**). There was a slight increase of total taxa at station 1AACO006.10 between the 1994-1996 and 2006-2008 sampling periods.

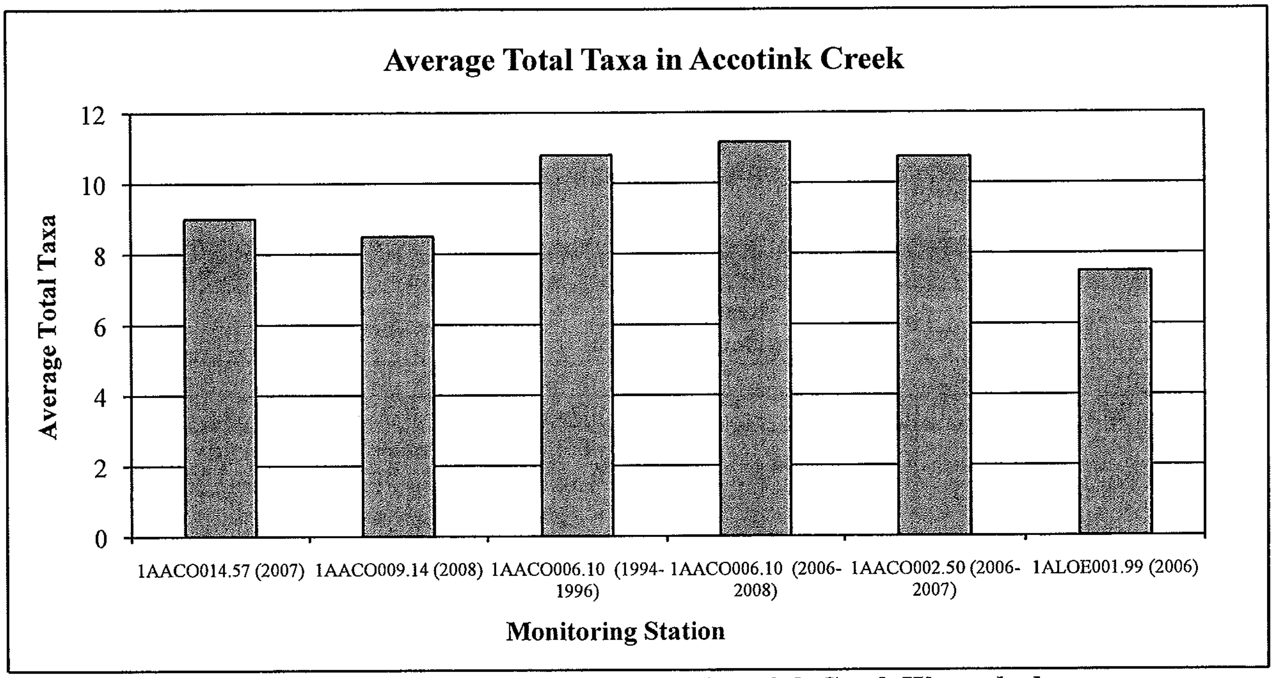

Figure 3-2: Average Total Taxa in the Accotink Creek Watershed

Another metric of taxonomic richness is the EPT (Ephemeroptera - mayflies, Plecoptera - stoneflies, Trichoptera - caddisflies) index. The EPT index is the number of families from the EPT orders in a sampling. Since the majority of the families in the EPT orders are intolerant of pollution and other environmental stressors, the EPT index is another indicator of benthic community health. At the Accotink Creek watershed monitoring stations, the EPT index ranged from 1 to 3 distinct EPT taxa with an average of 2 distinct EPT taxa.

b) Taxonomic Composition

The percentage of Ephemeroptera was calculated to measure the composition of mayfly nymphs within the sample. Since the majority of these species are highly sensitive to pollution and environmental stress, this metric is used as an indicator of stream health. The composition of mayflies was low in the impaired segment as well as upstream from the impaired segment A15R-01-BEN (**Figure 3-3**). In the samplings conducted at station 1AACO006.10 between 1994 and 1996, the composition of mayflies ranged from 0.0% to 2.9% with an average of 0.8%. In the 2006-2008 samplings conducted at station 1AACO006.10, the composition of mayflies ranged from 0.0% to 20.0% with an average of 3.9%. At station 1AACO002.50, the percent composition of mayflies ranged from 0.0% to 11.7% with an average of 3.2%. At station 1AACO009.14, the percent composition of mayflies was 0%. At station 1AACO014.57, upstream of the impaired segment A15R-01-BEN, the percent composition of mayflies ranged from 0.0% to 4.6% with an average of 2.3%. At station 1ALOE001.99, upstream of the impaired segment, the percent composition of mayflies ranged from 1.0% to 6.7% with an average of 3.9%.

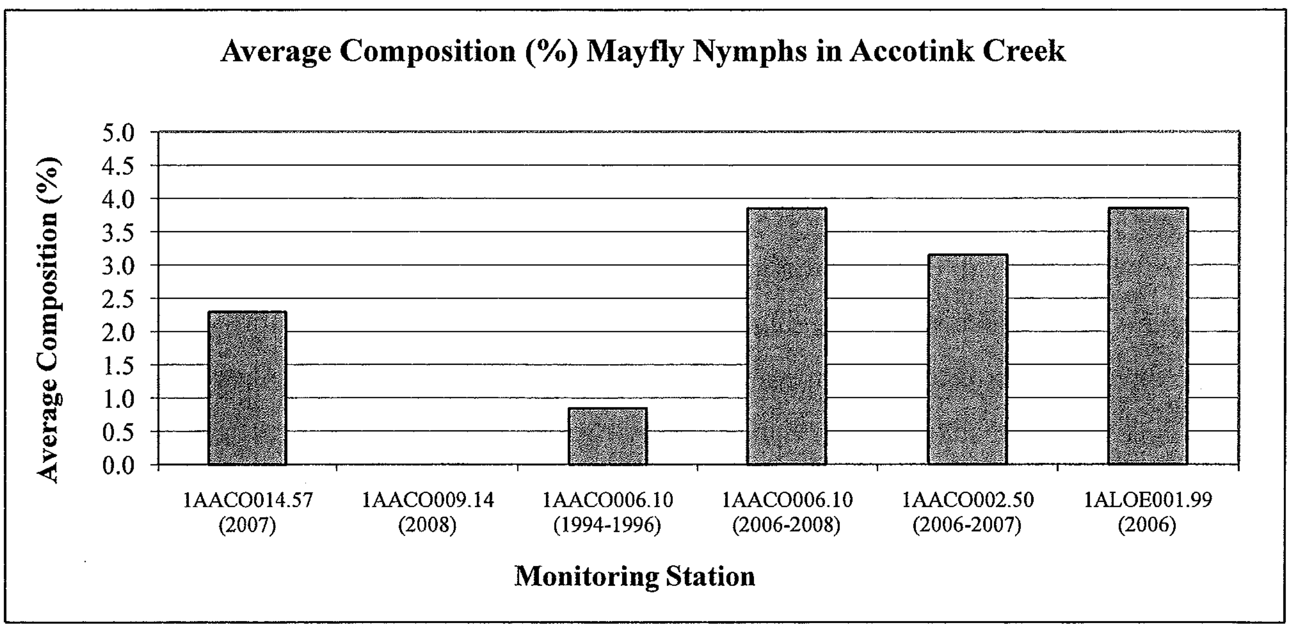

Figure 3-3: Average Percent Composition of Mayfly Nymphs in the Accotink Creek Watershed

The percentage of Chironomidae was calculated to measure the composition of midge larvae within the sample. Because midge larvae are tolerant to many stressors, this metric is expected to increase with increasing pollution and environmental stress. The composition of midge larvae generally increased from upstream to downstream in Accotink Creek (**Figure 3-4**).

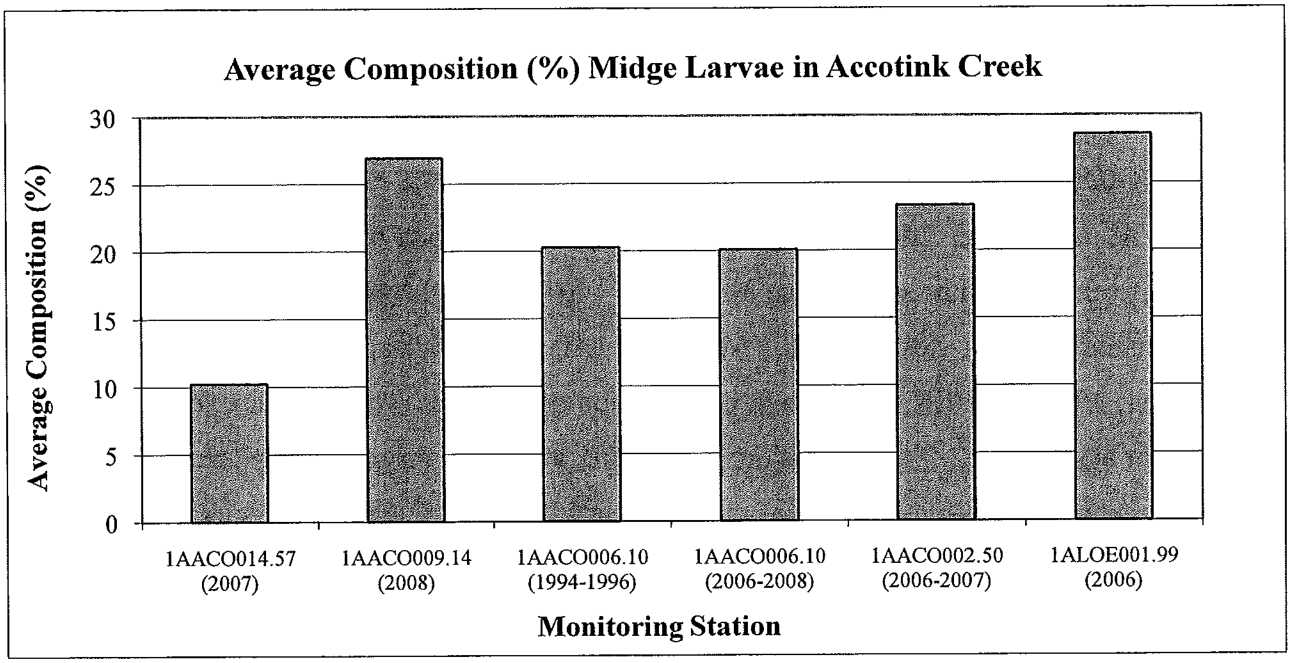

Figure 3-4: Average Percent Composition of Midge Larvae in the Accotink Creek Watershed

c) *Balance and Diversity*

The percentage of the two most abundant taxa was calculated as a measure of the community balance within the sample. As with taxa richness, a community in a polluted stream will most often be dominated by a few taxa. In the Accotink Creek watershed, samples from all stations were dominated by two taxa. In the samples collected between 1994 and 2008, the percentage of the two most abundant taxa ranged from 46% to 95% with an average of 71% (**Figure 3-5**). At station 1AACO006.10, the percentage of the two most abundant taxa increased between the 1994-1996 and 2006-2008 sampling periods.

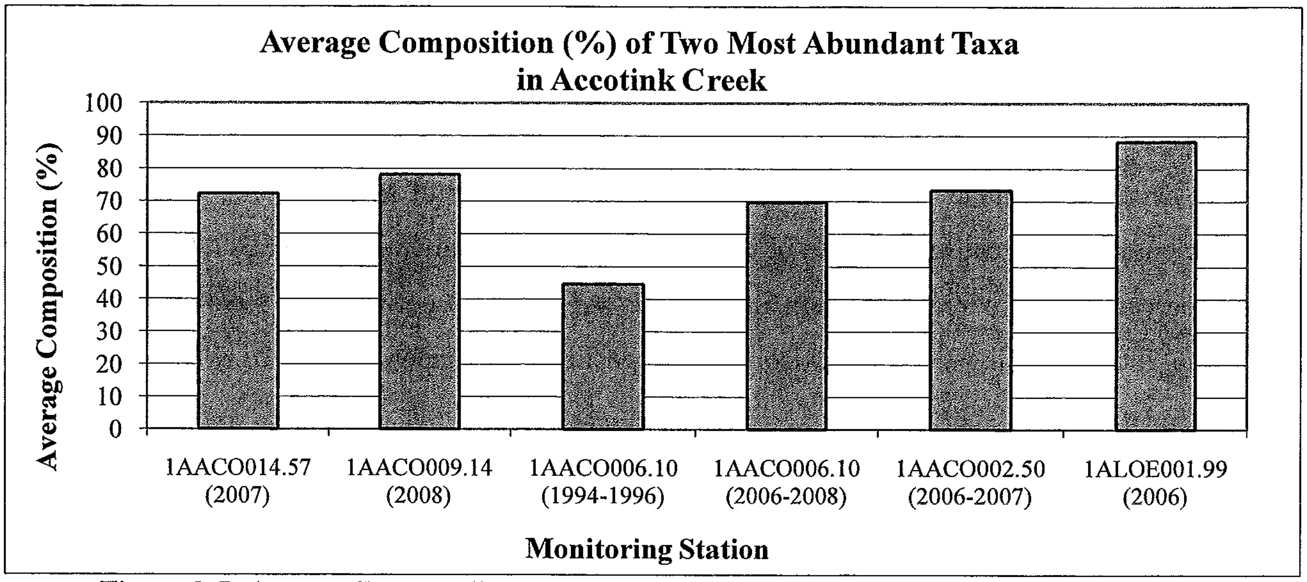

Figure 3-5: Average Percent Composition of Two Most Abundant Taxa in the Accotink Creek Watershed

d) Tolerance

Hilsenhoff's Biotic Index (HBI) is calculated as a measure of a macroinvertebrate community's tolerance to pollution. HBI scoring is on a scale from zero to ten, with zero indicating unpolluted conditions. In collected samples the HBI scores ranged from 5.7 to 7.1 with an average score of 6.2 (**Figure 3-6).** There was a slight decrease of the HBI score at station 1AACO006.10 between the 1994-1996 and 2006-2008 sampling periods.

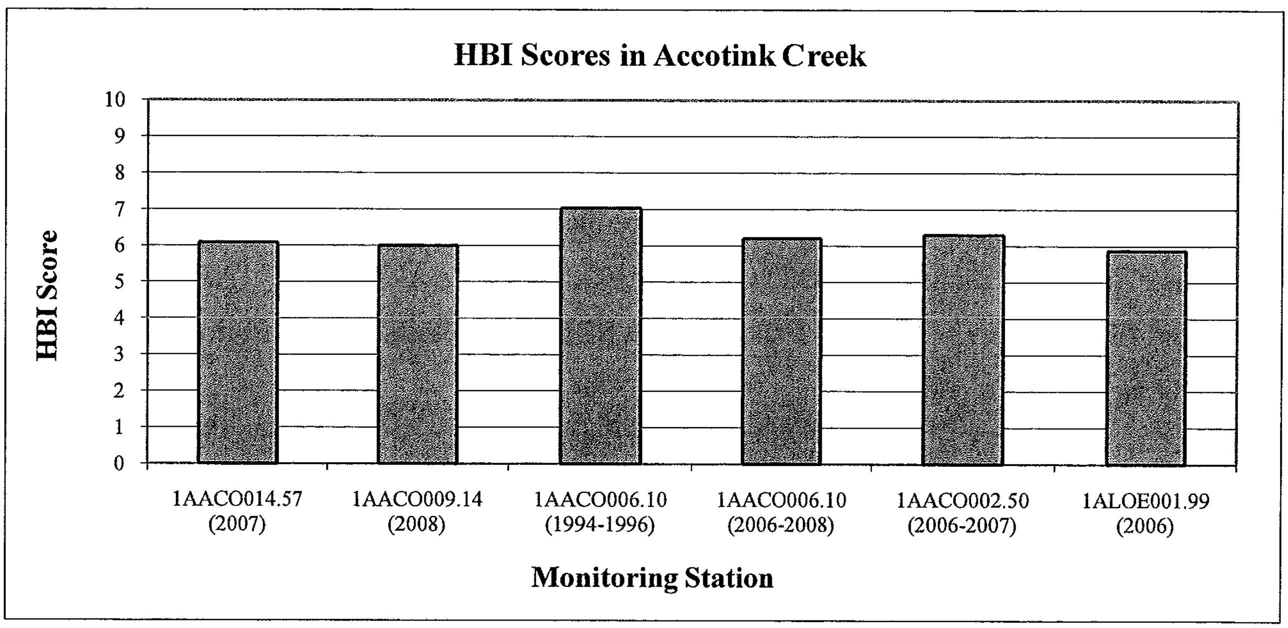

Figure 3-6: HBI Scores in the Accotink Creek Watershed

e) Trophic Group

Some macroinvertebrates feed by scraping the thin layer of algae at the surface of stream substrata. The abundance of scrapers tends to increase with increased diatom abundance, and decrease as algae and mosses accumulate. High levels of sediment, and organic or nutrient pollution causes declines in scraper numbers. As shown in **Figure 3-7,** there was a decrease of the percent scrapers at station 1AACO006.10 between the 1994-1996 and 2006-2008 sampling periods. Also, the composition of scrapers decreased downstream from station 1AACO006.10.

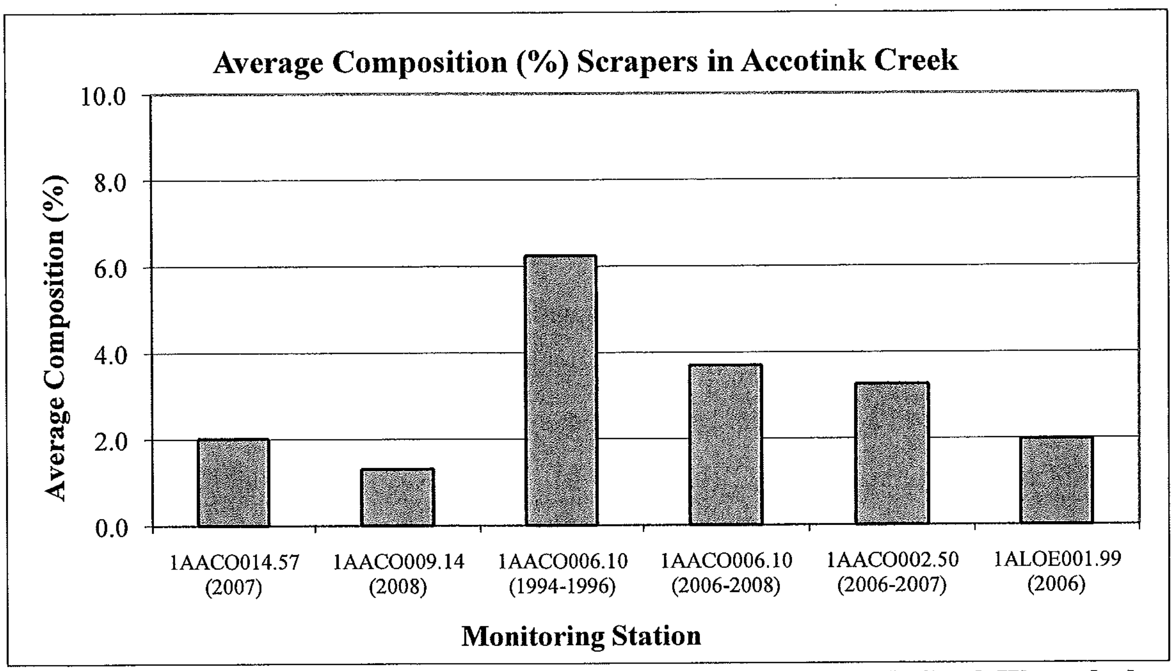

Figure 3-7: Average Percent Composition of Scrapers in the Accotink Creek Watershed

f) VSCI Results

The data discussed in the sections above were included by DEQ in calculating the VSCI scores for the stations 1AACO002.50, 1AACO006.10, 1AACO009.14, 1AACO014.57 and 1ALOE001.99. **Table 3-3** shows the VSCI score results for the stations that are discussed in this report.

Table 3-3: VSCI Scores for the Accotink Creek Watershed

Collection Period	1AACO002.50	1AACO006.10	1AACO009.14	1AACO014.57	1ALOE001.99
Fall 1994	-	38.3	-	-	
Spring 1995	-	38.9	-	-	
Fall 1995	-	30.6	-	-	
Spring 1996	-	38.2	-	-	
Fall 1996	-	28.3	-	-	
Spring 2006	35.3	24.3	-	-	29.5
Fall 2006	26.6	41.9	-	-	24.5
Spring 2007	33.5	36.6	-	31.6	
Fall 2007	28.3	29.7	-	30.9	
Spring 2008	-	25.7	22.8	-	
Fall 2008	-	35.9	30.7	-	
Average	**30.9**	**34.8[1]/32.4[2]**	**26.8**	**31.2**	**27.0**

[1]Average VSCI score at 1AACO006.10 from 1994 to 1996
[2]Average VSCI score at 1AACO006.10 from 2006 to 2008

During the collection period of 1994 through 2008, VSCI scores were below the impairment cutoff of 60.0 (**Figure 3-8**) in the Accotink Creek watershed. The VSCI scores for the 2006 to 2008 samplings ranged between 22.8 and 41.9 with an average score of 29.6. At station 1AACO006.10, the average VSCI scores decreased between the 1994-1996 and 2006-2008 sampling periods.

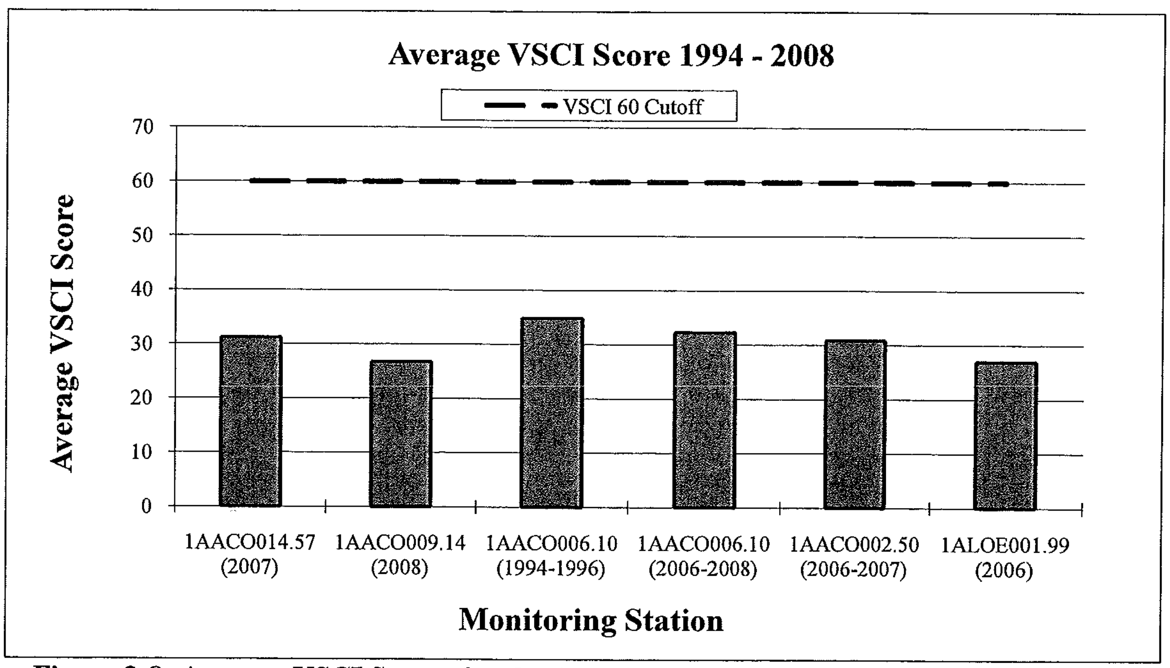

Figure 3-8: Average VSCI Scores for the Accotink Creek Watershed between 1994 and 2008

3.1.2 Habitat Assessment

A suite of habitat variables were visually inspected by DEQ at monitoring stations as part of the biological assessments conducted in the Accotink Creek watershed. Habitat parameters that were examined along the impaired segment include epifaunal substrate, embeddedness, velocity, sedimentation, channel flow, channel alteration, frequency of riffles, bank stability, bank vegetative protection, and riparian zone. During each sampling event, parameters were assigned a score from 0 to 20, with 20 indicating optimal conditions, and 0 indicating very poor conditions. Habitat assessment scores for the biomonitoring stations in the Accotink Creek watershed are presented in **Table 3-4.**

Table 3-4: Habitat Scores for Accotink Creek Watershed

Station	Sampling Season	Epifaunal Substrate	Embeddedness	Velocity	Sediment Deposition	Channel Flow	Channel Alteration	Frequency of Riffles	Bank Stability[1]	Bank Vegetative Protection[1]	Riparian Zone[1]	Total Habitat Score
1AACO014.57	Spring 2007	17	16	16	16	13	18	17	9	11	11	144
	Fall 2007	12	12	15	7	8	17	9	4	8	12	104
	Average	15	14	16	12	11	18	13	7	10	12	124
1AACO009.14	Spring 2008	11	12	15	12	19	16	11	10	10	10	126
	Fall 2008	16	15	15	15	14	18	13	7	6	12	131
	Average	13.5	13.5	15	13.5	16.5	17	12	8.5	8	11	129
1ACCO006.10	Fall 1994	3	14	16	8	16	10	15	14	15	5	116
	Spring 1995	9	17	17	10	17	12	15	14	16	12	139
	Fall 1995	6	17	18	11	18	10	16	16	17	10	139
	Spring 1996	11	18	18	9	18	11	16	14	17	10	142
	Fall 1996	12	17	18	15	18	12	17	16	14	14	153
	Spring 2006	8	6	12	10	12	15	12	10	12	12	109
	Fall 2006	7	4	14	6	18	11	13	10	12	9	104
	Spring 2007	13	11	15	10	10	18	15	10	18	19	139
	Fall 2007	10	10	15	7	10	17	17	7	9	16	118
	Spring 2008	7	15	17	14	19	16	16	4	6	18	132
	Fall 2008	14	15	13	8	13	17	14	5	7	18	124
	Average[2]	10	10	14	9	14	16	15	8	11	15	121
1AACO002.50	Spring 2006	8	8	13	6	9	14	7	8	12	14	99
	Fall 2006	3	2	15	2	17	4	13	7	10	18	91
	Spring 2007	13	11	15	10	12	17	11	10	20	20	139
	Fall 2007	8	10	15	5	8	17	16	7	11	18	115
	Average	8	8	15	6	12	13	12	8	13	18	111
1ALOE001.99	Spring 2006	11	8	7	7	10	15	14	12	12	9	105
	Fall 2006	8	14	13	7	6	12	17	4	14	10	105
	Average	9.5	11	10	7	8	13.5	15.5	8	13	9.5	105

[1]The total score is presented here. The left and right banks are scored separately.
[2]Average scores for 2006-2008 samplings

Overall, the habitat assessment scores from 2006-2008 were generally low at all stations in the Accotink Creek watershed with scores ranging between 91 and 144 with an average score of 118. Scores for habitat metrics such as epifaunal substrate, embeddedness, sediment deposition, and bank stability, were consistently low for the stations on the impaired segment A15R-01-BEN of Accotink Creek (**Figure 3-9**). The following is a summary of the four habitat metrics that scored low for the whole watershed:

- The epifaunal substrate metric is a measure of the relative quantity and variety of natural structures in the stream for spawning and nursery functions of aquatic macrofauna. In the Accotink Creek watershed, scores from the 2006-2008 samplings ranged between 3 and 17 with an average score of 10. Earlier samplings at station 1AACO006.10 also yielded similar scores.
- The embeddedness metric is the extent to which rocks and snags are covered or sunken in silt, sand, or mud in the stream bottom. In the Accotink Creek watershed, scores from the 2006-2008 samplings ranged between 2 and 16 with an average score of 11. Scores from earlier samplings at 1AACO006.10 were much higher, ranging between 14 and 18 with an average of 17. All of the habitat scores, including embeddedness, describe optimal conditions at the higher end of the scale and degraded conditions at the lower end. Although somewhat counterintuitive, a high embeddedness score indicates little to no silt or sand covering the rocks and snags, while a low embeddedness score indicates a greater quantity of silt or sand covering the rocks and snags. Therefore, going from a higher average score (17) in earlier samplings to a lower average score (11) in 2006-2008 indicates degradation over time.
- The sediment deposition metric is the amount of sediment that has accumulated in pools and the changes that have occurred to the stream's bars or islands due to deposition. Lower scores would indicate large-scale movement of sediment is occurring in the stream. Sediment deposition scores from the 2006-2008 samplings ranged from 2 to 16 with an average of 9. Earlier samplings at 1AACO006.10 yielded similar scores with a range between 8 and 15 and an average score of 11.
- The bank stability metric is the measure of whether stream banks have eroded or have the potential for erosion. Scores from the 2006-2008 samplings ranged between 4 and 12 with an average of 8. Earlier samplings at 1AACO006.10 had slightly higher scores with a range between 14 and 16 and an average score of 15.

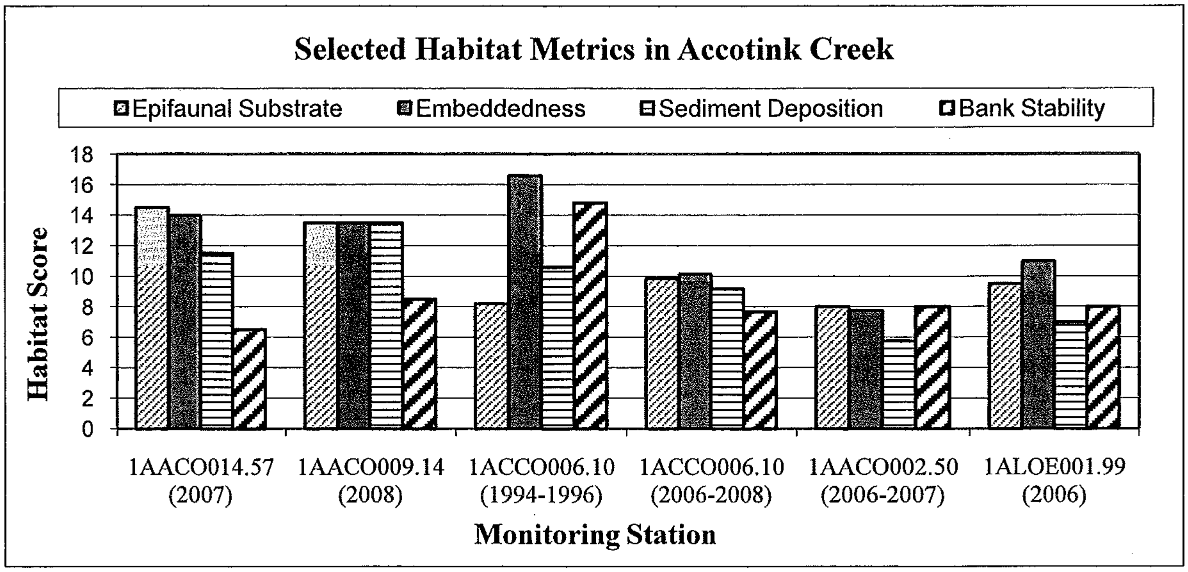

Figure 3-9: Selected Habitat Metrics in the Accotink Creek Watershed

The following are notes taken by DEQ biologists during the habitat assessment.

- Fall of 1994 - Watershed heavily impacted by NPS pollution. Evidence of substrate scouring, low organism densities, and reduced taxa, notably EPT
- Spring of 1995 - Impacted from stormwater discharges and heavy development of watershed (typical of streams in Northern Virginia)
- Fall of 1995 - Continual impacts from storm sewer runoff are responsible for reduced benthic fauna in this heavily urbanized watershed
- Fall of 1996 - Urban NPS continue, and will continue, to impact water quality in heavily urbanized watershed

3.1.3 Potential Impact of Lake Accotink on the Lower Segment of Accotink Creek

Lake Accotink is a large impoundment (68 acres) that is located in the middle of the Accotink Creek watershed (**Figure 3-1**). The assessment of the biological monitoring data (Section 3.1.1) and habitat data (Section 3.1.2) were performed at all the monitoring stations including stations located above (1AACO14.57) and below (1AACO009.14) Lake Accotink. This analysis indicated that there is no significant difference in the biological and habitat metrics above and below Lake Accotink, indicating that the physical and biological impairments above and below the lake are comparable. If Lake Accotink has an impact on the lower segment, it does not preclude the observed impairment, instream degradation, bank scouring and incision observed in both the lower and upper watershed segments. The impairment and instream degradation are widespread throughout the Accotink watershed and any potential impact of Lake Accotink is nullified by the much larger impact caused by the urban conditions and high impervious cover within the watershed. Thus, the hydrologic characteristics of the upper and lower portions of the watershed are similar resulting in similar hydrologic response and instream impacts in the lower and upper sections of the watershed.

To complement the assessment of the monitoring data presented in the previous sections, the levels of imperviousness above and below the Lake Accotink are estimated in **Table 3-5**. Such analysis indicates that the level of imperviousness is similar in the two segments, resulting in a high impervious level of 24.8% and 24.6% in the upper and lower segment respectively. As highlighted in Appendix C, the amount of impervious surface in a watershed is a key landscape indicator that directly influences watershed hydrology. High levels of imperviousness in both segments of the watershed will cause significant and similar aquatic life impairments due to habitat loss, erosion, channel widening, and streambed alteration in the lower as well the upper segments.

Table 3-5: Impervious Levels in the Upper and Lower Accotink Creek Watershed

Land Use Category	Impervious Level (percent)*	Upper Accotink Creek		Lower Accotink Creek	
		Acres	Impervious Acres	Acres	Impervious Acres
Estate Residential	5	292.4	14.6	90.9	4.5
Golf Course	1	202.8	2.0	483.3	4.8
High Density Residential	32	1,744.5	558.2	1,258.3	402.7
High Intensity Commercial	76	459.2	349.0	297.7	226.3
Industrial	50	401.8	200.9	1,546.9	773.5
Institutional	26	1,094.9	284.7	369.1	96.0
Low Density Residential	8	2,572.8	205.8	713.0	57.0
Low Intensity Commercial	58	643.8	373.4	199.3	115.6
Medium Density	14	5,191.5	726.8	2,463.0	344.8
Open Space	1	2,188.3	21.9	3,526.4	35.3
Transportation	59	2,724.1	1,607.2	1,842.2	1,086.9
Total		**17,516.1**	**4,344.6**	**12,790.1**	**3,147.3**
* Based upon Fairfax County Planimetric Land Use Data (Fairfax County, 2002)		**Impervious Level**	**24.8%**	**Impervious Level**	**24.6%**

3.1.4 Relative Bed Stability Studies

Excess sedimentation is one of the most prevalent and harmful stressors to benthic macroinvertebrate communities (VADEQ, 2008b; Van Sickle et al., 2006; USEPA, 2006). Until recently, tools for rapidly quantifying sedimentation impacts in streams have been inadequate. Methods existed for describing dominant particle size, but it was difficult to differentiate between natural conditions and man-made problems. Virginia has a variety of stream types; many are naturally sand/silt bed streams, so simply measuring the size of the sediment particles cannot differentiate natural and human-influenced sediment load.

EPA researchers have developed a methodology for predicting the expected substrate size distribution for streams (Kaufmann et al., 1999; Kaufmann et al., 2007). This methodology incorporates stream channel shape, slope, flow and sediment supply, and calculates 'stream power' based on channel measurements to predict the expected sediment size distribution. The logarithm ratio of the observed sediment to the expected sediment is a measure of the relative bed stability (LRBS). LRBS numbers around zero indicate the stream is stable (i.e., the stream is carrying the appropriate mean particle size for its calculated stream power). Increasingly negative LRBS numbers indicate excess sediment, while positive LRBS numbers signify sediment removal. This sediment removal leads to "stream hardening" which may indicate a stream that has eroding banks and an altered hydrology that affects the stream bottom. Another example of "stream hardening" occurs just downstream of some large reservoir projects. The reservoir acts as a large sediment trap, leaving the downstream river reach abnormally devoid of sediment.

2008 LRBS Data Collection on Accotink Creek

DEQ conducted an initial LRBS study on Accotink Creek at Station 1AACO006.10 at Route 790 (Alban Road) in November 2006. To further aid in TMDL development, follow-up LRBS studies were conducted at three sites along Accotink Creek in June 2008: Station 1AACO004.84 at Route 611 (Telegraph Road), Station 1AACO006.10 at Route 790 (Alban Road), and Station 1AACO009.14 at Route 636 (Hooes Road).

The additional data collected by DEQ allowed for the calculation of several quantitative habitat metrics, including percent slope in reach, mean particle size, LRBS, and percent fines (particles less than 2 mm). At station 1AAC004.84 the mean particle size is closer to coarse gravel (**Table 3-6**). The mean sediment particle size in Accotink Creek at stations 1AAC006.10 and 1AAC009.14 is within the cobble (64 to 250 mm) range (**Figure 3-10**). Additionally, the mean sediment particle size in the upper Accotink stations are in the upper quartile statewide, and are greater than the average mountain ecoregion stream (Hill, 2008 – Appendix D).

Table 3-6: Logarithmic Mean Particle Size Percentile in Accotink Creek

Station ID	Logarithmic Mean	Percentile[1]
1AAC004.84	1.17	73rd
1AAC006.10 (2006)	1.57	98th
1AAC006.10 (2008)	1.35	79th
1AAC009.14	1.44	83rd

[1]Based on Statewide Data

Figure 3-10: Example of Mean Particle Size Commonly Found Along the Impaired Reach of Accotink Creek. June 2008 RBS Study, Station 1AACO006.10

The LRBS at stations 1AAC006.10 and 1AAC009.14 are some of the most positive LRBS numbers recorded statewide (**Table 3-7**). The lower station, 1AAC004.84, is more normal, although high for LRBS scores in Virginia. Positive LRBS numbers indicate the stream has less sediment than expected based on the stream morphology.

Table 3-7: LRBS Percentile in Accotink Creek.		
Station ID	**LRBS**	**Percentile[1]**
1AAC004.84	-0.04	88^{th}
1AAC006.10 (2006)	0.55	98^{th}
1AAC006.10 (2008)	0.56	95^{th}
1AAC009.14	0.72	99^{th}
[1]Based on Statewide Data		

The percent fines are in the lower quartile statewide (**Table 3-8**). These numbers are particularly low for piedmont ecoregion streams and lower than the average mountain ecoregion stream (Hill, 2008).

Table 3-8: Percent Fines Percentile in Accotink Creek.		
Station ID	**Percent Fines**	**Percentile[1]**
1AAC004.84	18%	15^{th}
1AAC006.10 (2006)	19%	18^{th}
1AAC006.10 (2008)	24%	20^{th}
1AAC009.14	19%	18^{th}
[1]Based on Statewide Data		

High slope streams in the western mountains of Virginia explain some naturally high LRBS scores (**Table 3-9**). High slope streams tend to have higher stream powers and are consequently dominated by larger particle sizes. Accotink Creek's slope is moderately low and does not explain these excessively stable LRBS numbers (Hill, 2008). Accotink Creek's slope would typically result in less stable LRBS numbers, although stability decreased as one traveled downstream (from the 99^{th} percentile to the 88^{th} percentile, **Table 3-7**).

Table 3-9: Slope Percentile in Accotink Creek		
Station ID	**Slope**	**Percentile[1]**
1AAC004.84	0.52	30^{th}
1AAC006.10 (2006)	0.22	14^{th}
1AAC006.10 (2008)	0.17	11^{th}
1AAC009.14	0.22	14^{th}
[1]Based on Statewide Data		

Analysis of Relative Bed Stability Results:

Analysis of the relative bed stability studies indicate that altered hydrology has led to a scoured, eroded stream (**Figure 3-11**), which leaves behind a higher than expected median particle size.

Figure 3-11: Stream Bank Erosion Typical of Accotink Creek. June 2008 RBS Study, Station 1AACO004.84

In addition, it appears that fine sediment has been transported out of the upper reaches of Accotink Creek, which has led to some of the highest LRBS scores in the Virginia RBS habitat database. Sediment that erodes from the banks of Accotink Creek along the impaired segments is deposited further downstream in the Accotink watershed, closer to the tidal boundary (**Figures 3-12** and **3-13**).

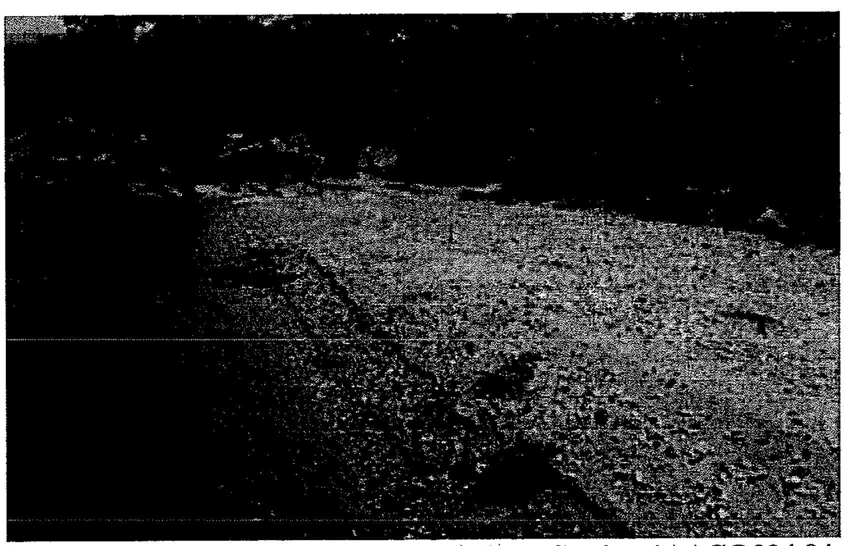

Figure 3-12: Coarse Gravel and Sediment Deposits at Station 1AACO004.84 (Telegraph Road)

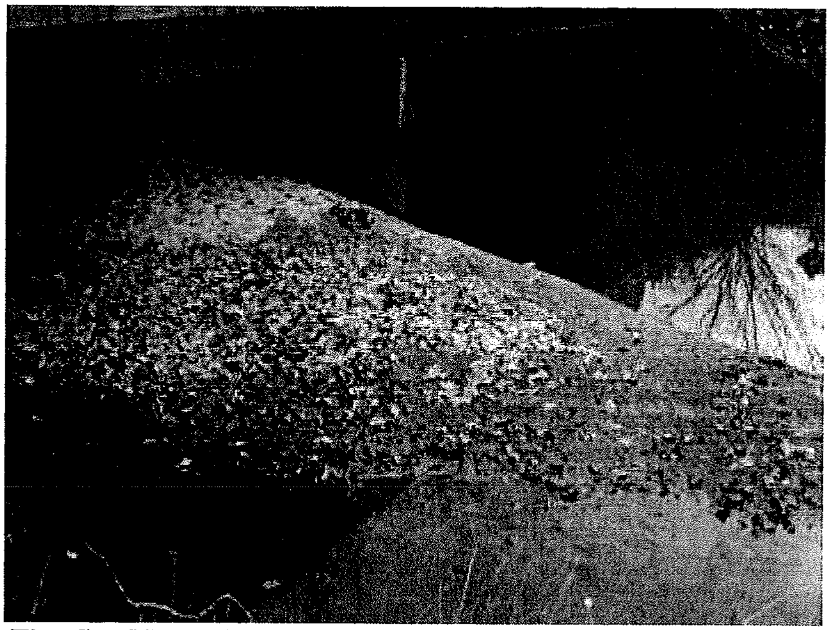

Figure 3-13: Fine Sand Deposit Located Under the Route 1 Bridge over Accotink Creek, near the Tidal/Non-Tidal boundary

3.1.5 Ambient Water Quality Monitoring

Data from water quality monitoring stations throughout the Accotink Creek watershed were used in the development of this TMDL (**Table 3-10**). DEQ collected instream water quality measurements for field-obtained parameters such as temperature, dissolved oxygen (DO), pH, and specific conductance, and lab-obtained parameters such as nutrients, suspended solids, metals, and organic contaminants. The river sediment measurements included metals and organics. For the analysis, data collected since 1990 was analyzed and compared to DEQ water quality standards.

Table 3-10: Water Quality Monitoring Stations Used for the Accotink Creek Stormwater TMDL

Station ID	Station Description	First Sample Date	Last Sample Date
1AACO002.50	Route 1	5/9/2005	6/12/2006
1AACO004.84	Route 611 (Telegraph Rd)	8/11/2005	6/4/2007
1AACO006.10	Route 790	10/17/1990	4/24/2007
1AACO009.14	Route 636 (Hooes Rd)	5/30/2008	10/31/2008
1AACO014.57	Route 620	10/17/1990	12/2/2009
1AACO019.29	Route 699	8/11/2005	8/11/2005
1AACO021.28	Route 237 (Pickett Rd)	5/22/2002	6/19/2002
1AACO021.70	Accotink Creek at Old Lee Highway	2/15/2006	2/15/2006
1ALOE001.99	Downstream from Route 651 (Guinea Rd)	6/1/2006	9/19/2006
1ALOA000.17	Route 611	8/11/2005	2/27/2006

A summary of measured instream data is presented below:

- DO data presented in **Figure 3-14** indicate that adequate levels of DO are found in the Accotink Creek watershed. The DO values for the Accotink Creek watershed range from 6.25 to 16.0 mg/L and averaged 10.5 mg/L. Neither DEQ criteria, a Daily Average Limit of 5 mg/L and a Minimum Limit of 4 mg/L, were exceeded.

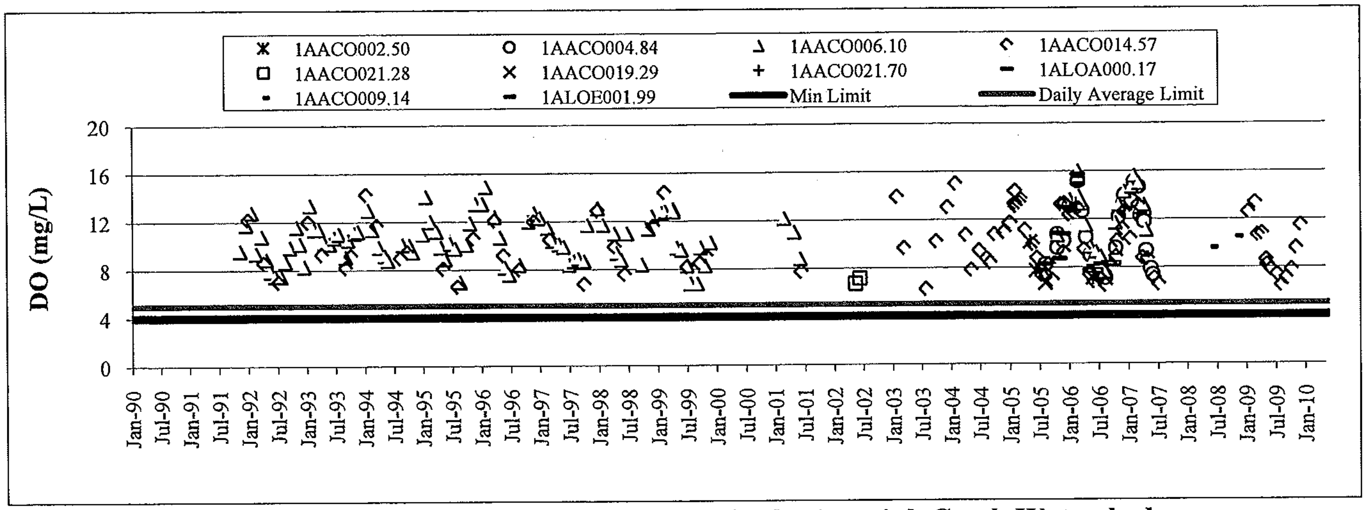

Figure 3-14: Ambient Dissolved Oxygen in the Accotink Creek Watershed

- All field pH values were in compliance with DEQ criteria (6.0 to 9.0 Standard Units) (**Figure 3-15**). pH ranged from 6.3 to 8.7 Standard Units with an average of 7.3 Standard Units.

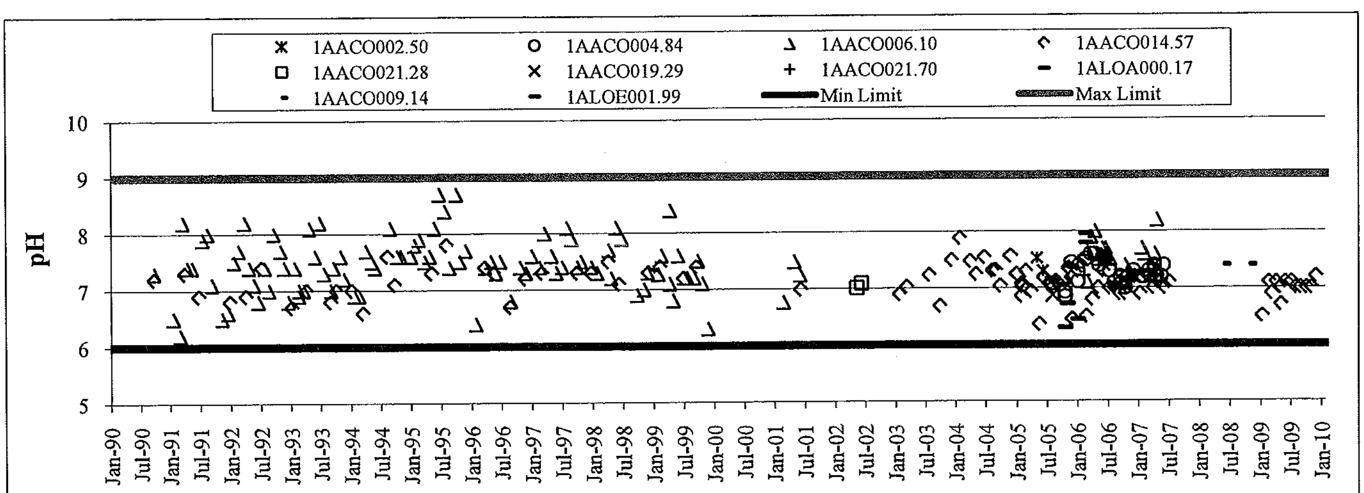

Figure 3-15: Ambient pH in the Accotink Creek Watershed

- All temperature values, which range from 0 to 29.8 °C and average 14.1 °C, were in compliance with DEQ criterion of a maximum of 32 °C (**Figure 3-16**).

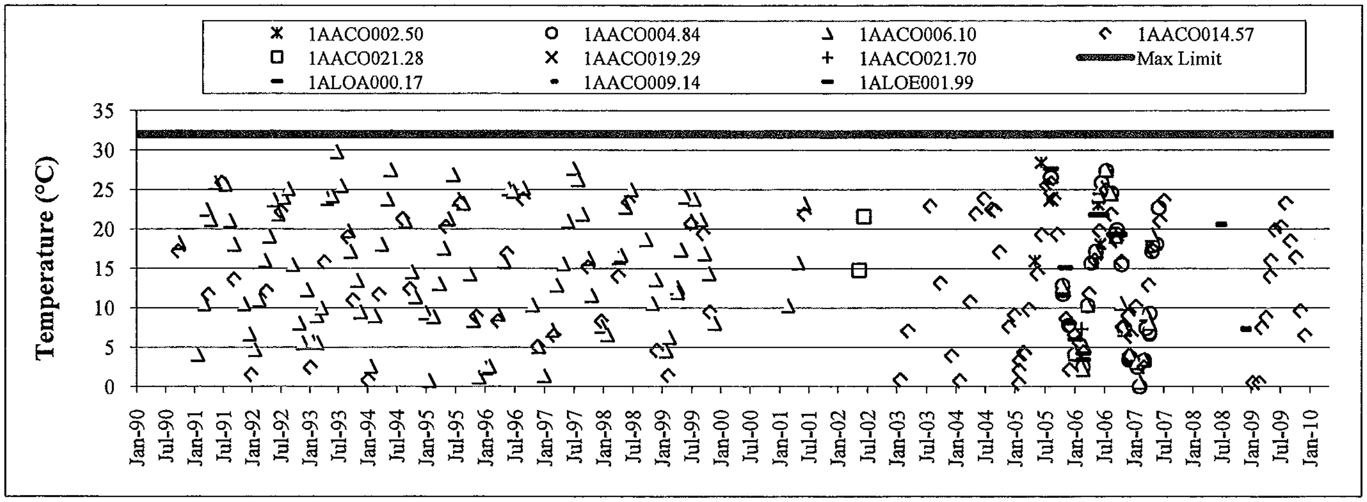

Figure 3-16: Ambient Temperature in the Accotink Creek Watershed

- Specific conductance levels measured at all stations ranged from 0 to 1,796 μmhos/cm with a total average of 268 μmhos/cm (**Figure 3-17**). There are no DEQ criteria or screening values for specific conductance. The spikes in conductivity typically occur during the winter months and are most likely connected to road salts and chemicals applied during winter storms.

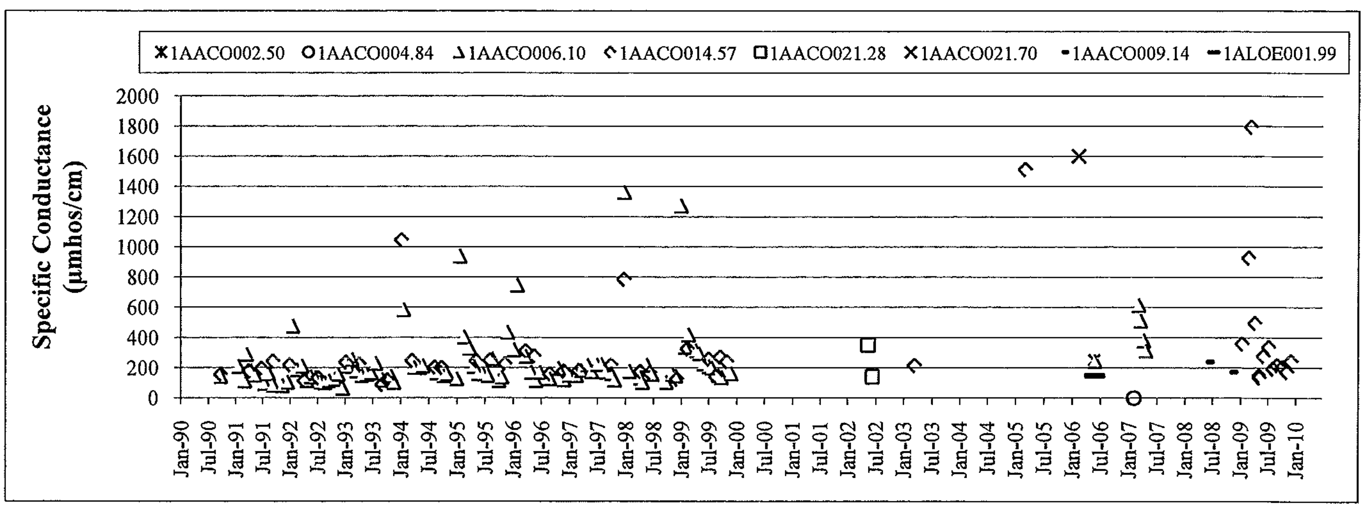

Figure 3-17: Ambient Specific Conductance in the Accotink Creek Watershed

➤ Biochemical oxygen demand (BOD_5) concentrations ranged from 1.0 to 16.0 mg/L with a total average of 2.2 mg/L (**Figure 3-18**). There are no DEQ criteria or screening values for BOD_5.

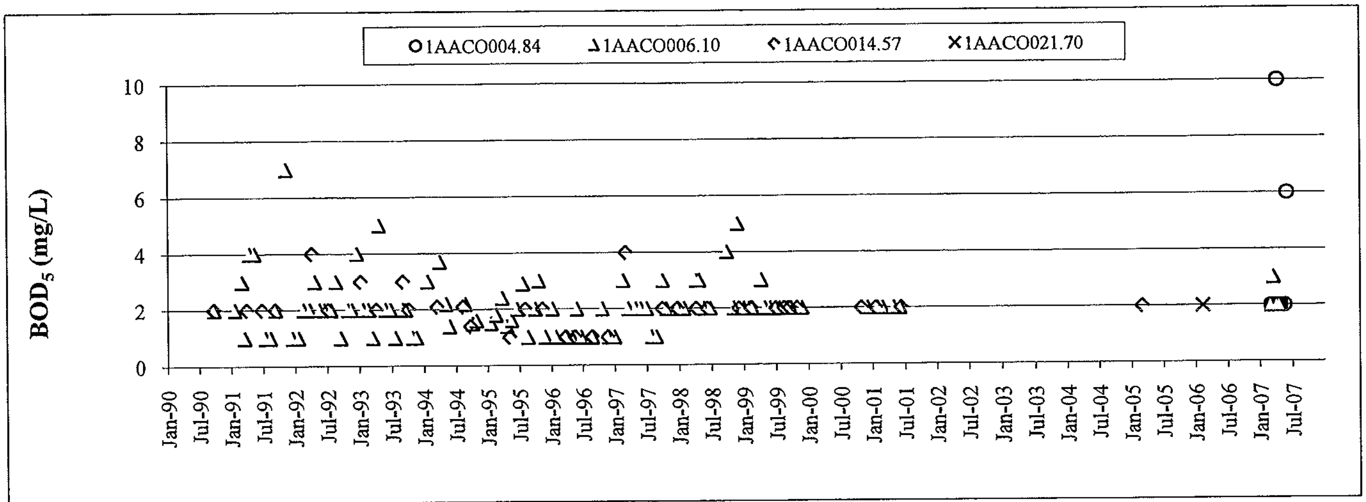

Figure 3-18: Ambient BOD_5 in the Accotink Creek Watershed

➤ Chloride concentrations ranged from 2.8 to 465 mg/L with a total average of 57.6 mg/L (**Figure 3-19**). The DEQ freshwater aquatic life criteria for chloride are established at 860 mg/L (Acute) and 230 mg/L (Chronic). Acute standards are applied for a one hour average concentration not to be exceeded more than once every 3 years on the average. Chronic standards are applied for a four-day average concentration not to be exceeded more than once every 3 years on the average. Chloride concentrations exceeded the chronic criterion on nine occasions; once at station 1AACO021.70, three times at station 1AACO014.57, and five times at station 1AAC006.10. Elevated chloride levels occurred most often in late winter and early spring months and are most likely connected to road salts and chemicals applied during winter storms.

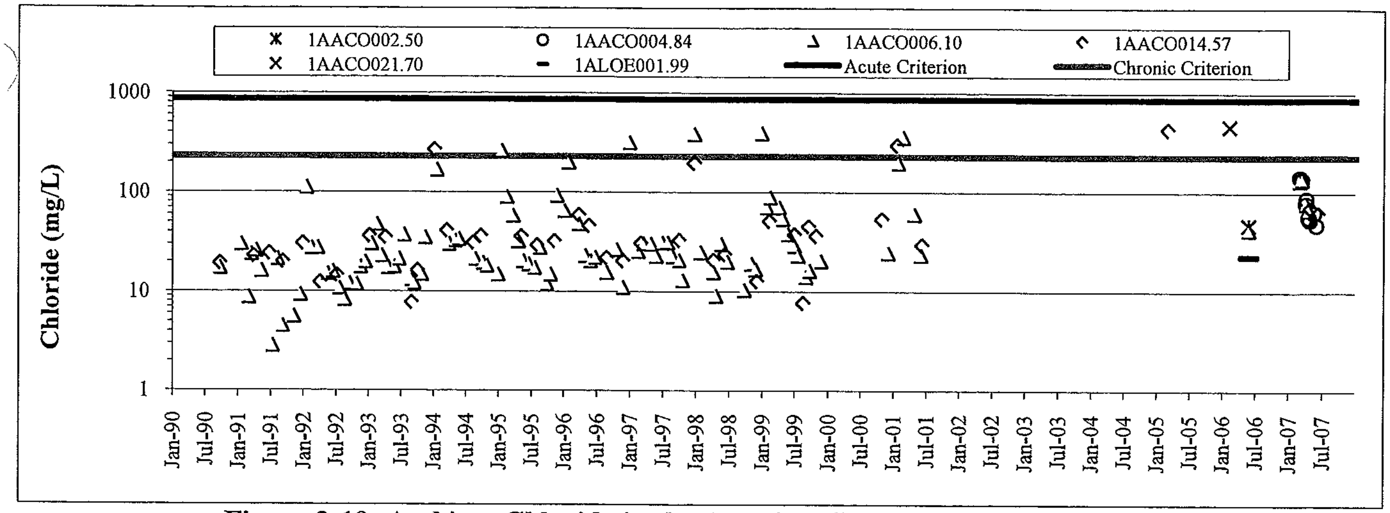

Figure 3-19: Ambient Chloride in the Accotink Creek Watershed

- Total suspended solids (TSS, total non-filterable residue) concentrations ranged from 1 to 227 mg/L with a total average of 13 mg/L (**Figure 3-20**). There are no DEQ criteria or screening values for TSS. **Figure 3-21** temporally compares TSS levels to flow conditions. It is worth noting that there are several instances in **Figure 3-21** where high TSS values do not coincide with high flow values. This is because the TSS and flow data presented in this figure were not collected concurrently from the same location in the watershed. Figure 3-21 represents all of the available TSS data collected from all of the monitoring stations on Accotink Creek along with the USGS flow data measured at Station 01654000 near Annandale, Virginia. The purpose of this figure is simply to present all the available TSS data regardless of the locations of the monitoring stations from which the TSS data was obtained.

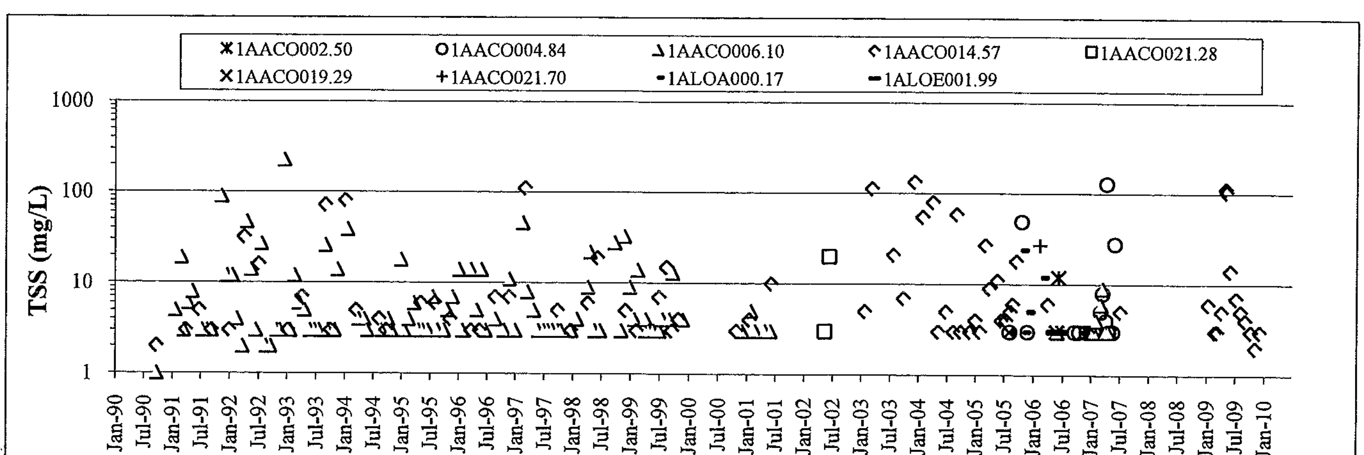

Figure 3-20: Ambient TSS in the Accotink Creek Watershed

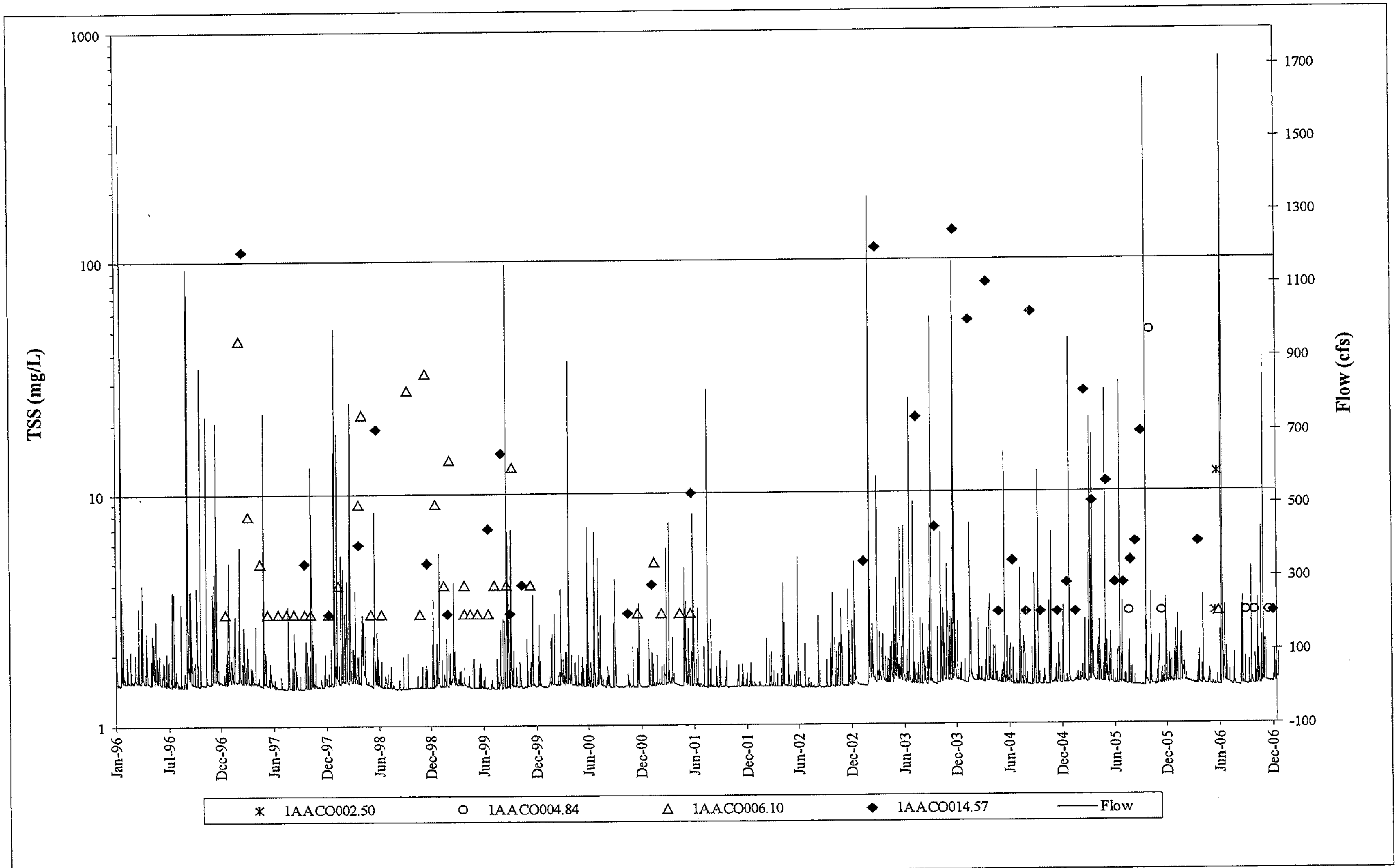

Figure 3-21: Ambient TSS and Flow in Accotink Creek between 1996 and 2006

- All total ammonia concentrations were in compliance with DEQ criteria, with a range of 0.008 to 1.26 mg/L and a total average of 0.07 mg/L (**Figure 3-22**).

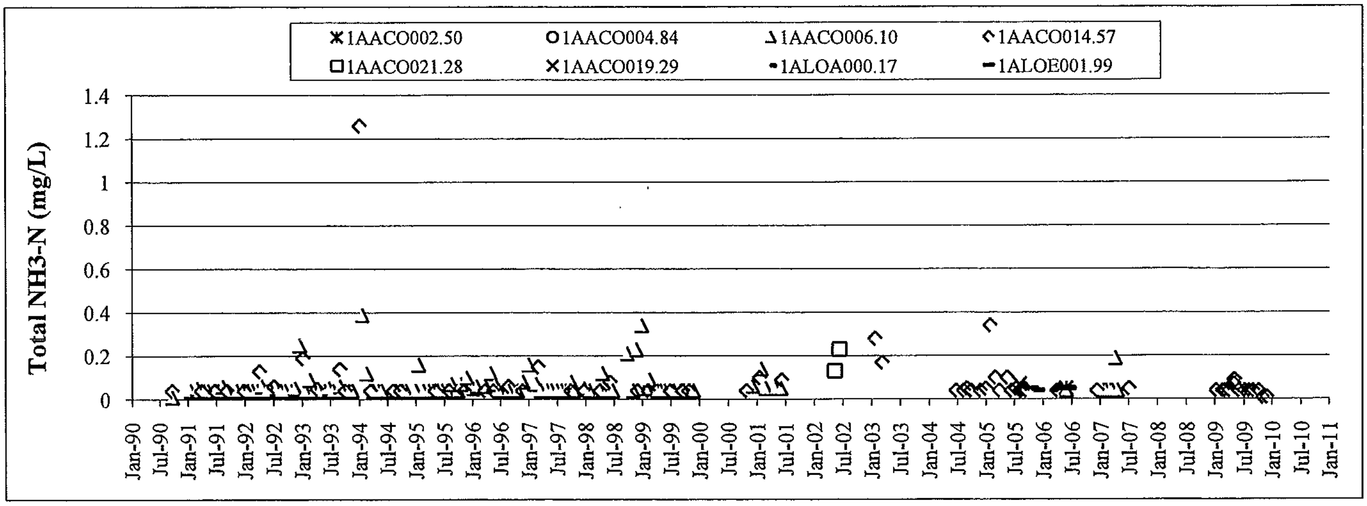

Figure 3-22: Ambient Total Ammonia in the Accotink Creek Watershed

- Nitrate (NO_3-N) concentrations were generally low. NO_3-N ranged from 0.01 to 41.0 mg/L with a total average of 0.84 mg/L (**Figure 3-23**). Virginia does not have numeric criteria against which to evaluate NO_3-N water quality monitoring data for free-flowing streams.

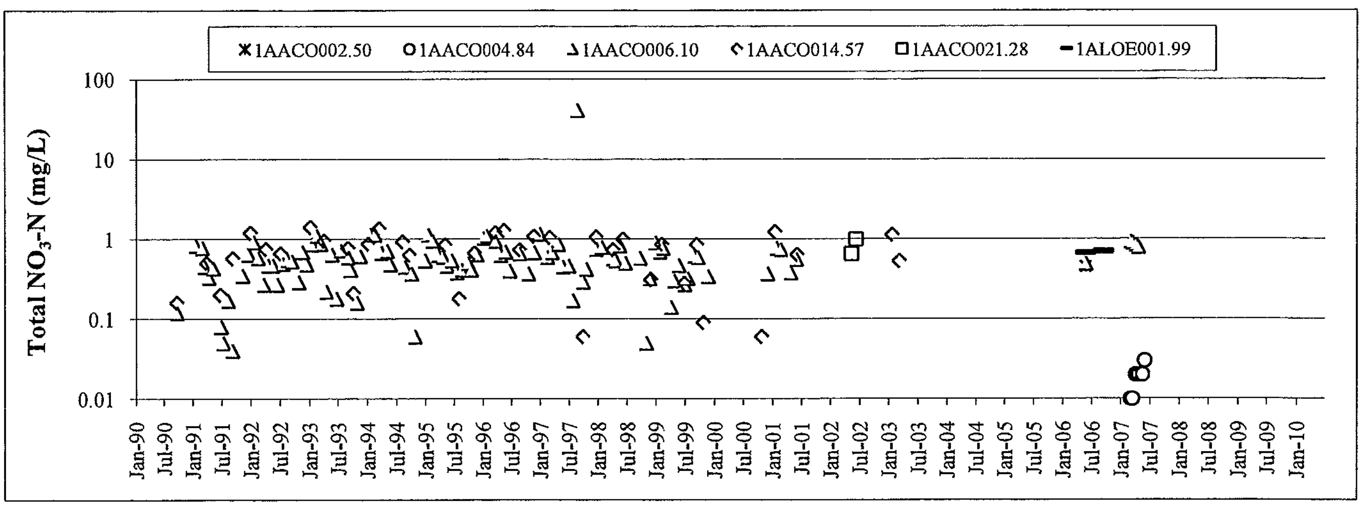

Figure 3-23: Ambient Nitrate in the Accotink Creek Watershed

- Total nitrogen (TN) ranged from 0.05 to 2.8 mg/L with a total average of 1.0 mg/L. Highest nitrogen levels were observed at station 1AACO014.57. It appears since 2003 TN values have been gradually decreasing. TN values exceed screening values in some locations (Screening values vary from 0.62 to 2.23 mg/L) (**Figure 3-24**). Virginia does not have numeric criteria against which to evaluate TN water quality monitoring data for free-flowing streams.

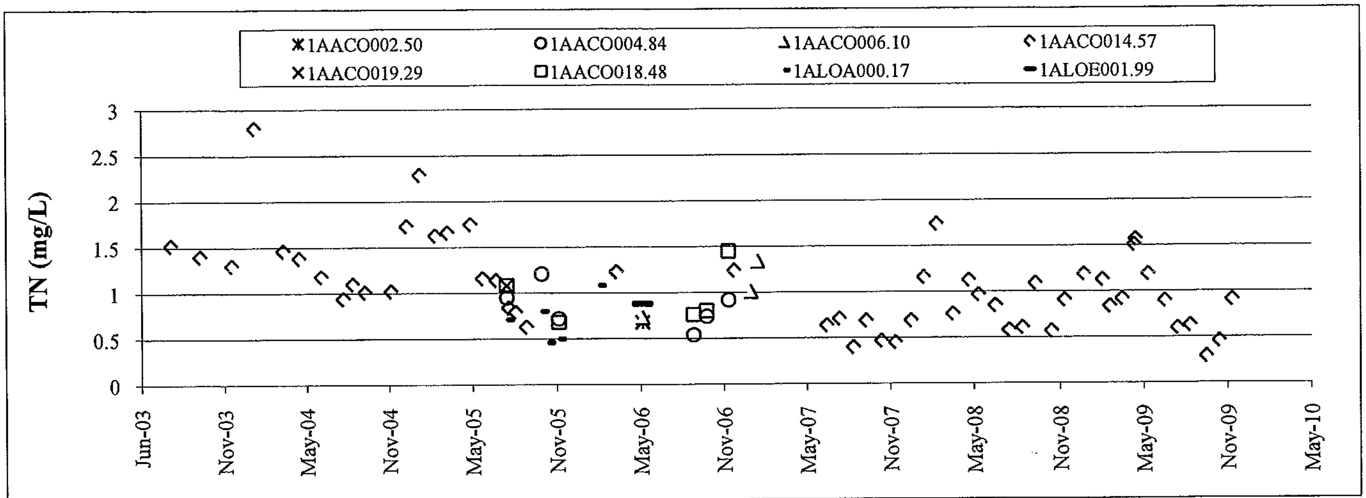

Figure 3-24: Ambient Total Nitrogen in the Accotink Creek Watershed

- Ortho-phosphorus (PO4-P) concentrations ranged between 0.002 and 0.1 mg/L with a total average of 0.02 mg/L (**Figure 3-25**). Virginia does not have numeric criteria against which to evaluate ortho-phosphorus water quality monitoring data for free-flowing streams.

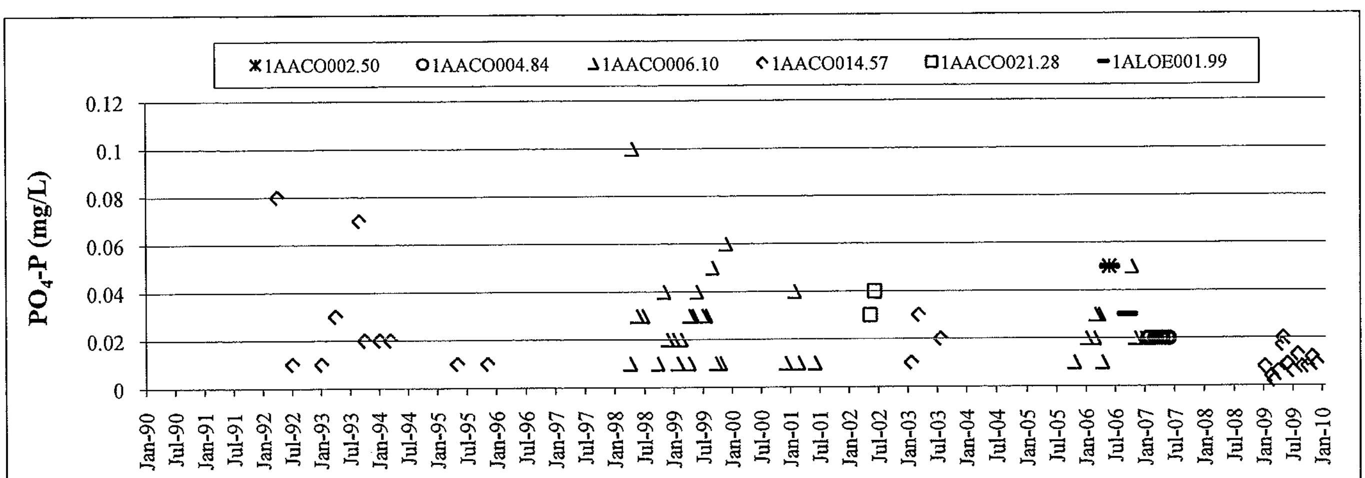

Figure 3-25: Ambient Ortho-phosphorus in the Accotink Creek Watershed

- Total phosphorus levels ranged from 0.01 to 0.3 with a total average of 0.08 mg/L. TP values exceed screening values in some locations (Screening values vary from 0.03 to 0.4 mg/L) (**Figure 3-26**). Virginia does not have numeric criteria against which to evaluate TP water quality monitoring data for free-flowing streams.

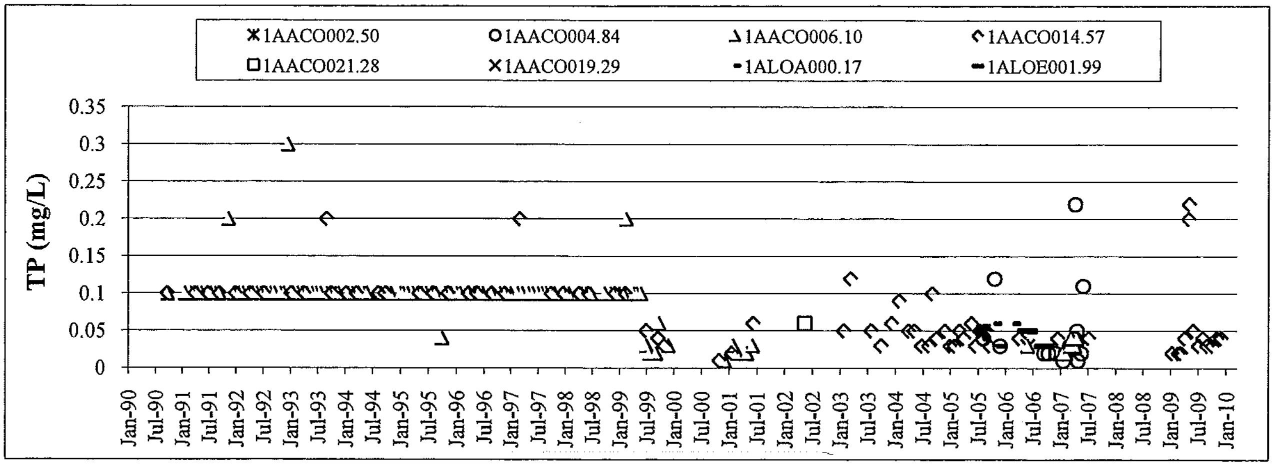

Figure 3-26: Ambient Total Phosphorus in the Accotink Creek Watershed

3.1.6 Metals Data

Dissolved metals concentrations were measured at monitoring stations 1AACO002.50, 1AACO004.84, and 1AAC006.10 within the benthic impaired segment, and at 1AACO014.57, upstream of the benthic impaired segment. Metals measured included aluminum, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc. All available dissolved metals data were assessed to determine compliance with Virginia's established water quality standards. No monitored metals parameters exceeded the acute or chronic dissolved freshwater criteria specified in Virginia's aquatic life use standards for dissolved metals.

3.1.7 Organic Contaminant Data

Instream organic contaminant data were collected at monitoring stations 1AACO002.50, 1AACO004.84, 1AAC006.10 and 1AACO014.57. Organic contaminants measured included aldrin, dieldrin, chlordane, dicofol, endrin, dichlorodiphenyltrichloroethane

(DDT), dichlorodiphenyldichloroethane (DDD), dichlorodiphenyldichloroethylene (DDE), heptachlor epoxide, heptachlor, and PCBs. No monitored organic contaminant parameters in the water column exceeded the acute or chronic dissolved freshwater criteria specified in Virginia's aquatic life use standards.

3.1.8 Continuous Ambient Instream Monitoring

DEQ conducted continuous instream measurements for temperature, dissolved oxygen, pH, and specific conductivity at one DEQ monitoring station (1AAC006.10) in the Accotink Creek watershed over five days in August of 2006 (**Table 3-11, Figures 3-27 to 3-31**). The DO fluctuation over 24 hours ranged from 0.96 to 2.16 and averaged 1.47 mg/L during this time period. There were no exceedances of the minimum criterion (4 mg/L). The decrease in specific conductance seen in **Figure 3-31** is due to a rainfall event that occurred on the morning of August 7th.

Table 3-11: Summary of Instream Continuous Measurements Over Five Days in the Benthic Impaired Segment of Accotink Creek

	Temp	DO	DO	pH	Spec. Cond.
	°C	mg/L	%	-	µS/cm
Average	27.0	6.9	86.1	7.3	219.8
Minimum	22.8	5.8	74.4	6.7	54.0
Maximum	30.1	8.6	100.0	7.5	248.0

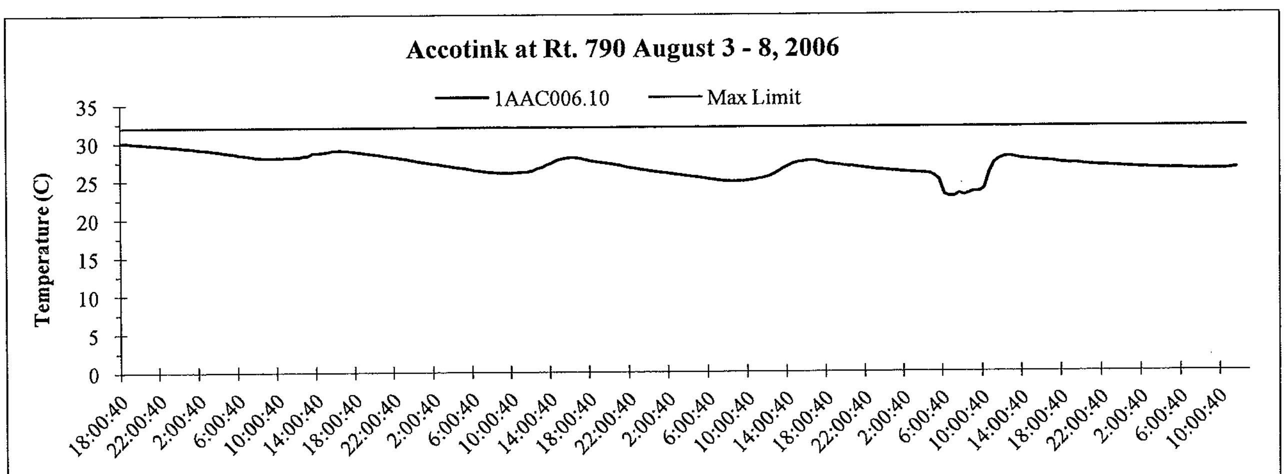

Figure 3-27: Continuous Ambient Monitoring of Temperature in Accotink Creek in August of 2006

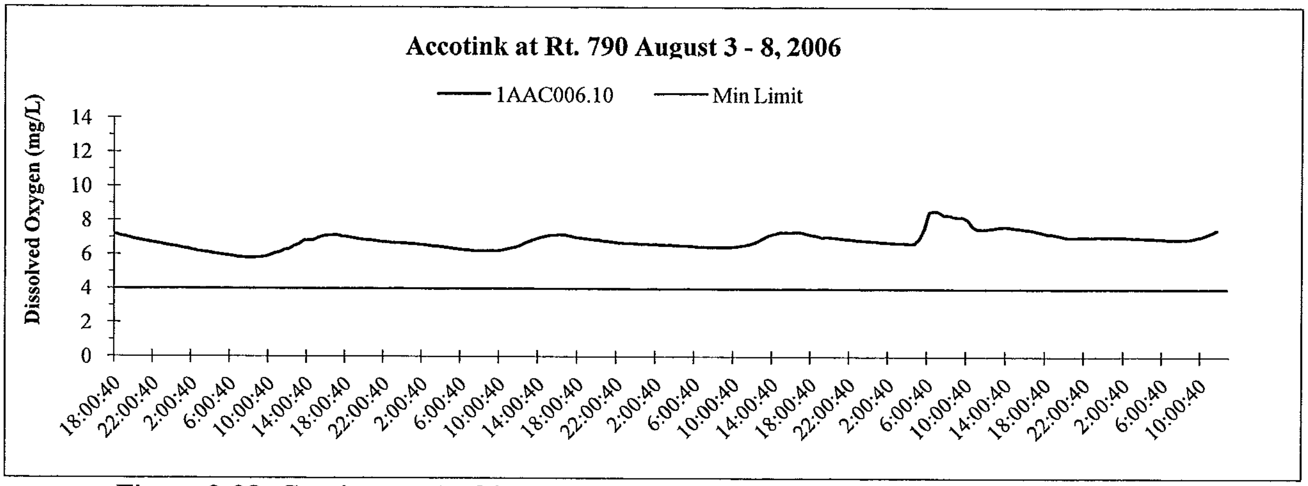

Figure 3-28: Continuous Ambient Monitoring of Dissolved Oxygen (mg/L) in Accotink Creek in August of 2006

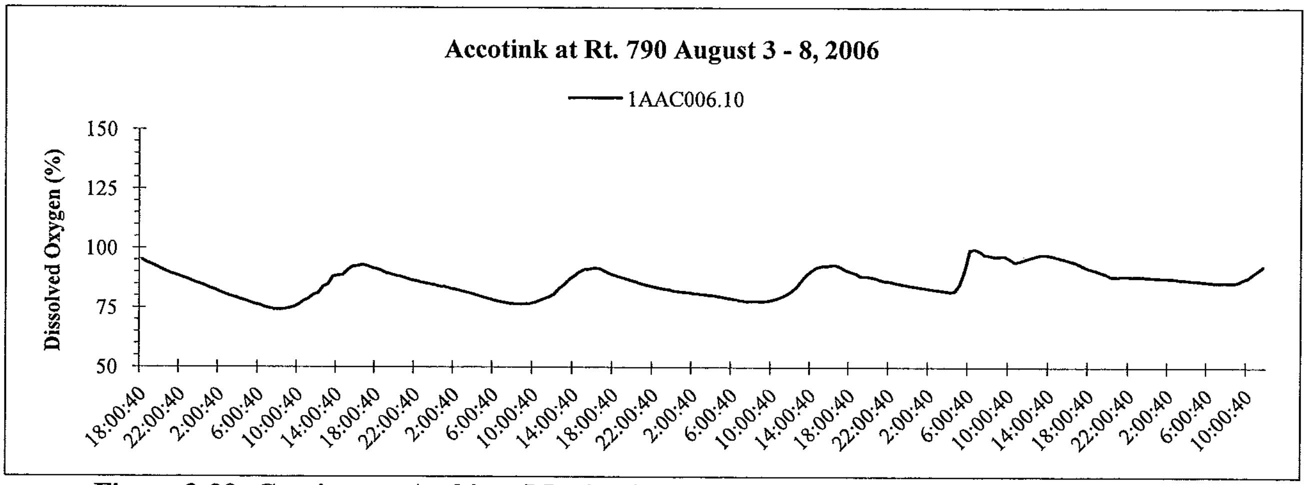

Figure 3-29: Continuous Ambient Monitoring of Dissolved Oxygen (%) in Accotink Creek in August of 2006

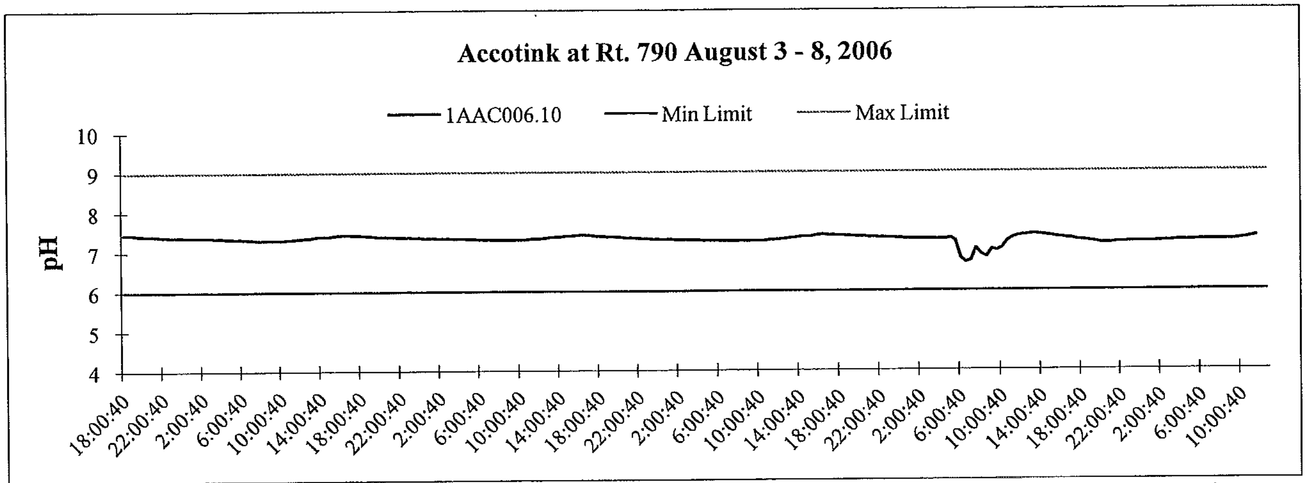

Figure 3-30: Continuous Ambient Monitoring of pH in Accotink Creek in August of 2006

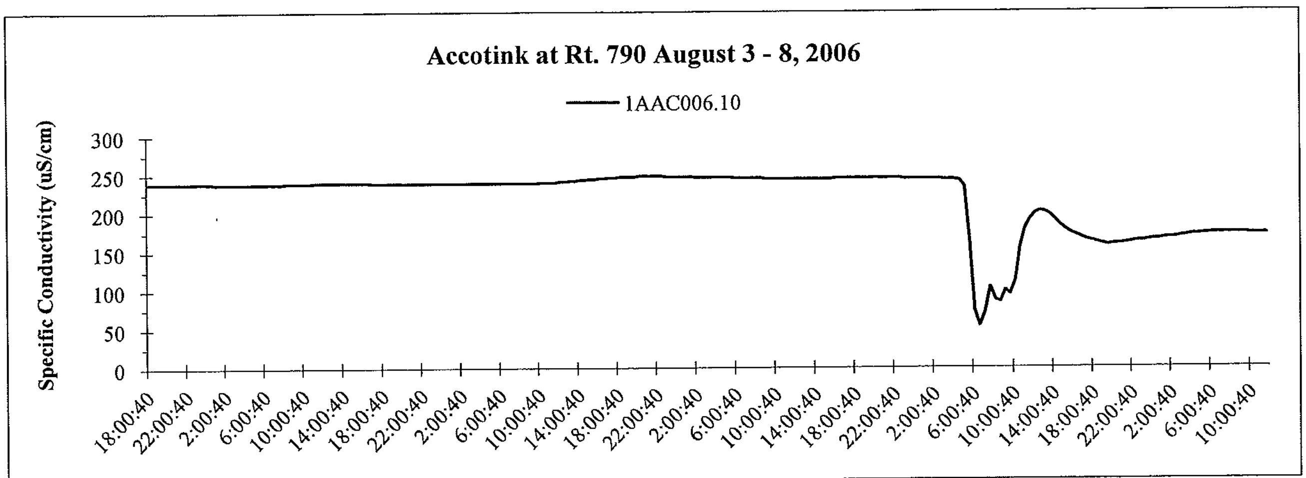

Figure 3-31: Continuous Ambient Monitoring of Specific Conductance in Accotink Creek in August of 2006

3.1.9 Fish Tissue and Sediment Contamination Monitoring Program

DEQ collects fish tissue and sediment data for two or three river basins per year. The data are used by DEQ to assess the environmental quality of Virginia's waters and by the Virginia Department of Health (VDH) to determine the need for fish consumption advisories. The monitoring program consists of a two-tiered sampling program. Tier I is a screening study that includes a high number of sampling stations in order to recognize areas of streams with contaminated stream sediment and fish tissue. When Tier I shows areas of contamination, a more intense study (Tier II) is conducted to determine the magnitude and geographical extent and potential source(s) of contamination in the sediments and fish.

DEQ collected both sediment and fish tissue samples at one monitoring station (1AACO004.86) located within the lower impaired segment of Accotink Creek (A15R-01-BEN) on two separate occasions, 6/20/2001 and 6/1/2004. Fish tissue samples were collected at two additional stations in the watershed in September of 2007 – one station located on Lake Accotink (1AACO012.78) and one station located downstream of the lake (1AACO012.58). In March of 2008 fish tissue samples were collected at two more stations – one station located below Accotink Lake Dam (1AACO011.62) and one station above Braddock Road (1AACO014.38). The collected sediments and fish tissues were analyzed for PAHs, PCBs, and metals, and then compared to DEQ Fish Tissue Values or Risk-Based Fish Tissue Screening Values (VADEQ, 2007). **Table 3-12** depicts the constituents analyzed by DEQ in the sediment and fish tissue samples. Fish tissues were obtained from three fish species representing top-level predators, mid-level predators, and bottom feeders.

Table 3-12: Constituents Analyzed in Sediment and Fish Tissue Samples

	Constituents in Sediment	Constituents in Fish Tissue*
PAHs	Total PAHs, naphthalene, 2-methyl naphthalene, 1-methyl naphthalene, biphenyl, ace-naphthylene, ace-naphthene, dibenzo furan, 2.3.5-trimethyl naphthalene, fluorene,dibenzo thiophene, phenanthrene, anthracene, 1-me phenanthrene, fluoranthene, pyrene, benza anthracene, chrysene, benzo (b) fluoranthene, benzo (k) fluoranthene, benzo(e) pyrene, benzo(a) pyrene, perylene, indeno(1,2,3-cd) pyrene, db(a,h) anthracene, and benzo(ghi) perylene	
PCBs and Halogenated Organics	Total PCBs, Total Chlordane, Sum dichlorodiphenyldichloroethylene (DDE), Sum dichlorodiphenyldichloroethane (DDD), Total dichloro-diphenyl-trichloroethene (DDT), Sum DDT, Heptachlor epoxide, gamma BHC, Total BHC, Endrin, Endrin Aldehyde, HCBs, OCDDs	Total PCBs, Total Chlordane, Sum dichlorodiphenyldichloroethylene (DDE), Sum dichlorodiphenyldichloroethane (DDD), Total dichloro-diphenyl-trichloroethene (DDT), Sum DDT, Total BDE, HCB, Heptachlor epoxide, Aldrin, Heptachlor, delta BHC, gamma BHC, Total BHC, Mirex, Dicofol
Metals	aluminum, silver, arsenic, cadmium, chromium, copper, mercury, nickel, lead, antimony, selenium, thallium, zinc	arsenic, cadmium, chromium, mercury, lead, selenium

* Fish tissues were analyzed from the following species: Redbreast Sunfish, American Eel, White Sucker, Yellow Bullhead Catfish

No exceedances of the screening values were found in the sediment. However, exceedances of measured constituents in fish tissue were found and are presented in the following summary.

Fish Tissue

- Concentrations of heptachlor epoxide found in the tissue samples from American eels (37.34 ppb) were greater than DEQ's fish tissue value (12 ppb) in the June 2001 sample at 1AACO004.86.
- Concentrations of total PCBs found in the tissue samples from American eels (201.86 ppb) were greater than DEQ's fish tissue value (54.0 ppb) in the June 2001 sample at 1AACO004.86.
- Concentrations of dieldrin found in the tissue samples from American Eel (25.77 ppb) were greater than DEQ's fish tissue value (6.7 ppb) in the June 2001 sample at 1AACO004.86.
- Concentrations of total PCBs found in the tissue samples from American Eel (241.90 ppb) were greater than DEQ's fish tissue value (54.0 ppb) in the March 2008 sample at 1AACO011.62.

- Concentrations of total chlordane found in the tissue samples from American Eel (541.49 ppb) were greater than DEQ's fish tissue value (310.0 ppb) in the March 2008 sample at 1AACO011.62.
- Concentrations of heptachlor epoxide found in the tissue samples from American Eel (17.36 ppb) were greater than DEQ's fish tissue value (12.0 ppb) in the March 2008 sample at 1AACO011.62.
- Concentrations of total PCBs found in the tissue samples from gizzard shad (92.11 ppb) were greater than DEQ's fish tissue value (54.0 ppb) in the September 2007 sample at 1AACO012.78.
- Concentrations of arsenic found in the tissue samples of yellow bullhead catfish (132 ppb) were greater than DEQ's fish tissue screening value (72 ppb) in September 2007 at 1AACO012.58.
- Concentrations of mercury found in the tissue samples of bluegill sunfish (374 ppb) and tissue samples from two largemouth bass (776 ppb and 435 ppb) were greater than DEQ's fish tissue screening value (300 ppb) in the September 2007 at 1AACO012.78.

3.1.10 Toxicity Testing

Toxicity testing using fathead minnows (*Pimephales promelas*) and water fleas (*Ceriodaphnia dubia*) was performed on water samples collected in Accotink Creek by DEQ. Fathead minnow testing was conducted over 7 days in October of 2005, using water samples from stations 1AACO004.84 and 1AACO006.10. The EPA Region 3 laboratory in Wheeling, West Virginia performed the chronic toxicity testing. Results indicated that water flea mortality and reproduction in the Accotink Creek water samples were not statistically different than that of the control samples. Based on the toxicity testing, there were no toxic water column effects to *Ceriodaphnia* in the Accotink Creek samples. The toxicity testing indicated that water samples from the Accotink Creek station 1AACO004.84 had adverse effects on fathead minnow survival and biomass. The EPA Region 3 laboratory in Wheeling indicated that in their professional judgment, these results "were probably biologically significant," and that the observed toxicity testing results should be compared with other water quality data collected at this site to determine the causes of toxicity. The effects of water samples from station 1AACO006.10 on fathead minnow survival were statistically different from lab samples, but there was no significant effect on minnow biomass. Biologists concluded that these results for station 1AACO006.10 "may or may not be indicative of a toxic effect." It should be noted that the toxicity testing data do not provide any information on the condition of the stream during the sampling.

3.2 Discharge Monitoring Reports

Discharge Monitoring Reports (DMRs) for each of the VPDES permitted facilities discharging into the Accotink Creek watershed were obtained and analyzed. This analysis showed that to date, all VPDES facilities currently discharging in the Accotink watershed were in compliance with their permit limits.

3.3 Other Monitoring Efforts – EPA and USGS Study

From December 2005 to March 2008, EPA and USGS monitored a restored portion of Accotink Creek in the northern part of the watershed (**Figure 3-32**). Findings of this study are represented in an EPA report "Evaluation of Receiving Water Improvements from Stream Restoration (Accotink Creek, Fairfax City, VA" (USEPA, 2008). This monitoring was designed to assess the effectiveness of the restoration activities on instream water quality. Restoration activities included planting of native species along the streambanks and installation of bioengineering structures to stabilize the stream bank and channel. EPA and USGS performed continuous and discrete water quality monitoring before and after the restoration. Monitoring consisted of water quality measurements for pH, temperature, turbidity, conductivity, water depth, and water velocity at locations upstream and downstream of the restoration. In addition, other physical, chemical, and bacteriological parameters were monitored during dry weather. Physical habitat monitoring was also performed prior to restoration, and biological collections of macroinvertebrates were made both before and after restoration. The study results indicate that stream restoration alone may have little effect on improving the conditions of in-stream water quality and biological habitat and emphasize that reduction of stormwater runoff rates and associated pollutants of concern should be addressed in the watershed through source control and stormwater retrofits to achieve desired biological outcomes.

As a result of the monitoring, the restored portion of Accotink Creek was listed as impaired for the aquatic life use in Virginia's 2008 Integrated Report. The new impaired segment on Accotink Creek (A15R-04-BEN) is 0.85 miles long, and begins at the confluence with an unnamed tributary located in Ranger Park and continues downstream until the confluence with Daniels Run.

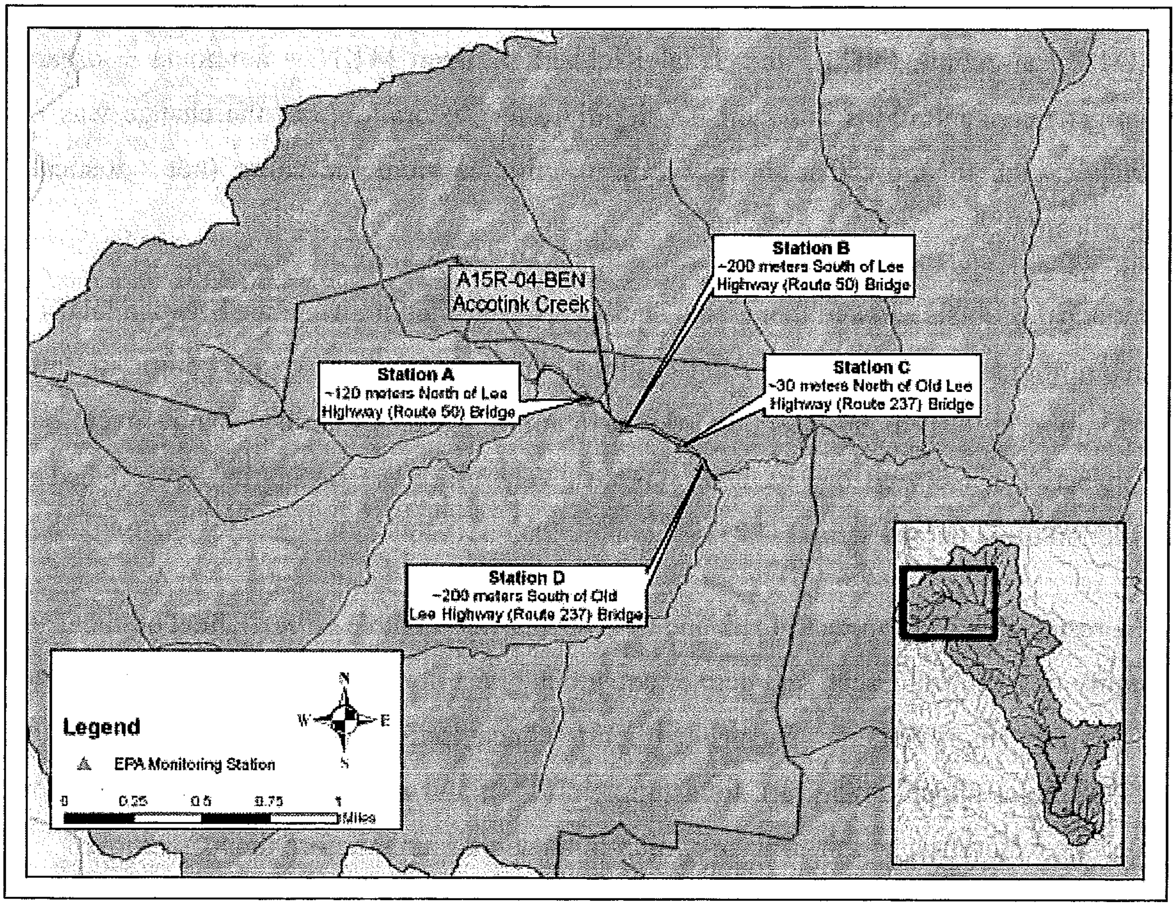

Figure 3-32: Locations of the EPA Monitoring Sites

3.3.1 Water Quality Results – EPA and USGS Study

The changes in continuously monitored pH, temperature, turbidity, and conductivity were similar to those seen prior to restoration and were mainly induced by seasonal effects or natural climatic events. Flow data did not change from pre-restoration measurements except where a monitoring station was moved to a new location. USGS sampling revealed no detectable change in the transport of sediment or bacteria and instream turbidity levels were similar before and after restoration.

The discretely monitored samples showed some differences. The wet weather suspended solids increased significantly after restoration (statistically significant) from 3 – 13 mg/L (before) and 97 – 291 mg/L (after) at the downstream location. Also, ortho-phosphorus (PO4-P), ammonia (NH3), and Total Kjeldahl nitrogen (TKN = ammonia + organic nitrogen) concentrations did increase slightly after restoration, but the change was not large enough to show that the restoration activities were the cause (not statistically significant).

Statistical analysis showed there is no statistically significant difference between levels of bacteriological constituents of fecal coliform, enterococci, and *E. coli* before and after restoration as well as upstream and downstream of the restoration. Changes were only seen between wet and dry weather samples. Therefore the restoration project had no effect on these parameters.

The restoration of the stream bank and channel seemed to have no real effect on the water quality of Accotink Creek and neither aquatic habitats nor stream bed conditions seemed to see any improvement. Suspended solids concentrations, chemical oxygen demand (COD), total phosphorus (TP), total nitrogen (TN), and ammonia (NH_3) concentrations after the restoration activities were similar to those measured before the restoration.

3.3.2 Biological Monitoring Results – EPA and USGS Study

Macroinvertebrate samples were collected by EPA in 2005, 2006, and 2007 and the stream water quality was evaluated based on the Virginia Stream Condition Index

(VSCI), the Hilsenhoff Biotic Index (HBI), number of Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa families, and number of total taxa families for all sampling events. **Table 3-13** and **Table 3-14** show the results. VSCI scores less than 60 indicate impaired conditions for macroinvertebrates. The HBI evaluates levels of nutrients or organic content with high levels falling at least in the "enriched" range of 4-7. Although the data was limited, the seasonal changes in the VSCI and the HBI that occurred before and after restoration treatment were not statistically significant and indicated that restoration was not a factor. According to VSCI scores, the restored area does not seem to have been improved by the restoration. However two years after the restoration, all sites showed a small increase in VSCI, HBI, and the EPT taxa index indicating a slight improvement in conditions between pre- and post-restoration. These changes in VSCI (P=0.014), HBI (P=0.012) and total number of EPT taxa families (P=0.017) were statistically significant and the change was greater than would be expected by chance, indicating that the restoration might have played a part in the improvement. That said, the VSCI and HBI scores, while showing an upward trend, were still well within the ranges indicating impairment and enrichment.

Table 3-13: Results of Macroinvertebrate Data*

	Date	Species	Site A (~120 m North of Lee Hwy) Upstream	Site B (~100 m South of Lee Hwy) Restoration Area	Site C (~10 m North of Old Lee Hwy) Restoration Area	Site D (~200 m South of Old Lee Hwy) Downstream	Site RUP (~50 m Wes. of Bridge at River Road) Upstream
Pre-Restoration	Nov. 3-4, 2005	VSCI	21.2	29.1	24.3	25.9	-
		HBI	6.86	5.87	5.94	6.06	-
		# of EPT Taxa Families	1	2	1	1	-
		# of Total Taxa Families	5	6	5	5	-
	Dec. 7-8, 2005	VSCI	21.5	25.1	30.7	25.6	28.5
		HBI	5.91	6.17	6.03	6.13	5.95
		# of EPT Taxa Families	1	1	1	1	1
		# of Total Taxa Families	5	5	9	6	6
	Mar. 13-14, 2006	VSCI	25.2	23.9	26.3	27.2	24.2
		HBI	6.03	6.82	6.03	6.59	6.13
		# of EPT Taxa Families	2	1	1	1	1
		# of Total Taxa Families	5	5	6	6	8
Post-Restoration	Sept. 21, 2006	VSCI	36.8	28.2	33.5	32.2	38.6
		HBI	6.02	5.9	5.75	5.71	5.28
		# of EPT Taxa Families	3	2	2	2	3
		# of Total Taxa Families	5	4	7	6	4
	Nov. 15, 2006	VSCI	29.6	26.6	28.4	24.8	33.3
		HBI	5.35	6.09	6.03	5.98	5.79
		# of EPT Taxa Families	2	1	2	1	2
		# of Total Taxa Families	6	5	7	5	10
	May 9, 2007	VSCI	27.9	22.8	12.3	22.2	26
		HBI	6.09	6.59	6.02	6.79	6.08
		# of EPT Taxa Families	3	1	0	2	2
		# of Total Taxa Families	7	5	3	5	6
	Sept. 18-19, 2007	VSCI	32	30.5	22.5	31.7	32.2
		HBI	5.9	5.93	6	5.86	5.84
		# of EPT Taxa Families	3	2	2	2	2
		# of Total Taxa Families	6	7	8	7	7
	Nov. 14-15, 2007	VSCI	27.1	28.5	30.4	29.2	28.8
		HBI	6.47	6.02	6.13	5.97	6.16
		# of EPT Taxa Families	1	1	1	1	1
		# of Total Taxa Families	6	7	8	6	9

* Table adapted from Evaluation of Receiving Water Improvements from Stream Restoration (Accotink Creek, Fairfax City), VA Report, 2008.

Table 3-14: Results of Macroinvertebrate Data Average Macroinvertebrate Indices and EPT Taxa Families Before and After Restoration*

	Site RUP		Site A		Site B		Site C		Site D	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
VSCI	26.4 (3.0)	31.8 (4.8)	22.6 (2.2)	30.7 (3.9)	26.0 (2.7)	27.3 (2.9)	27.1 (3.3)	28.7 (4.6)	26.2 (0.9)	28.0 (4.4)
HBI	6.04 (0.13)	5.83 (5.83)	6.27 (0.52)	5.96 (0.41)	6.29 (0.49)	6.11 (0.28)	6.17 (0.32)	5.99 (0.14)	6.26 (0.29)	6.06 (0.42)
EPT Taxa Families	1.00 (0.0)	2 (2.00)	1.33 (0.58)	2.40 (0.89)	1.33 (0.58)	1.40 (0.55)	1.00 (0.0)	1.40 (0.89)	1.00 (0.0)	1.60 (0.55)

* Table adapted from Evaluation of Receiving Water Improvements from Stream Restoration (Accotink Creek, Fairfax City), VA Report, 2008; Parentheses indicate standard deviation

Restoration caused no change in the total number of macroinvertebrate taxa, macroinvertebrate individuals, and percent dominant taxa upstream and downstream and before and after restoration. However, after restoration the composition was affected with more Hydropsychidae than Chironomidae, whereas before there were more Chironomidae than Hydropsychidae.

Stream channel cross section and pebble count measurements were taken before and after and upstream and downstream of the restoration. Following restoration, the depth of the upstream reach did not change although there was an increase in depth at the restored location. Even though there was a slight increase in sediment size downstream of the restoration reach, overall there was little change in particle size after restoration.

Most macroinvertebrate parameters such as total abundance, total number of individuals, and dominant species did not change pre- and post-restoration thereby indicating that stream conditions two years after restoration were the same as those found before. According to the USGS data, turbidity, sediment size, and flow levels were not affected by the restoration and occurred at the same levels as prior to restoration. Although the restoration was able to stabilize and improve stream banks, the project was not able to provide better conditions and habitat for aquatic organisms and allow for biological community improvement.

3.3.3 Recommendations – EPA and USGS Study

The study results show that the stream restoration did not improve the water quality of the restored reaches and indicate that stream restoration alone may have little effect on improving in-stream water quality and biological habitat conditions. The study emphasizes that the reduction of stormwater runoff and associated pollutants of concern should be addressed in the watershed through source control and stormwater retrofits to achieve desired biological outcomes. The study recommends that wet weather flow controls (i.e. stormwater BMPs) be strategically located in the watershed to reduce and delay stormwater runoff discharges to the stream.

4.0 Stressor Identification Analysis

TMDL development for a benthic impairment requires identification of the pollutant stressor(s) impacting the benthic macroinvertebrate community. Stressor identification for the biologically impaired segments of Accotink Creek was performed using the watershed characterization and environmental monitoring data discussed in Sections 2 and 3. The stressor identification was performed using guidelines outlined in EPA's Stressor Identification Guidance (USEPA, 2000).

The identification of the most probable cause of the biological impairments in Accotink Creek was based on evaluations of candidate stressors that can potentially affect the waterbody. The evaluation includes candidate stressors such as dissolved oxygen, temperature, pH, metals, organic chemicals, nutrients, toxic compounds, and sediments. Each candidate stressor was evaluated based on available monitoring data, field observations, and consideration of potential sources in the watershed. Each candidate stressor was then classified as one of the following:

Non-stressor: Candidate stressor with data indicating normal conditions, without water quality standard exceedances, or without any apparent impact on the benthic community.

Possible stressor: Candidate stressor with data indicating possible links to the benthic impairments, but without conclusive data to show a direct impact on the benthic community.

Most probable stressor: Candidate stressor with strong data linking it to the poor health of the benthic community.

Table 4-1 summarizes the results of the stressor analysis for Accotink Creek:

Table 4-1: Summary of Stressor Identification in Accotink Creek
Non-Stressors
pH
Temperature
Dissolved Oxygen
Instream Metals
Possible Stressors
Nutrients (Nitrogen, Phosphorus)
Toxicity
Metals and Organic Contaminants in Fish Tissue
Most Probable Stressors
Stormwater Runoff and Sedimentation

4.1 Non-Stressors

4.1.1 pH

Benthic invertebrates require a suitable range of pH conditions. Although these ranges may vary by invertebrate phylogeny, in general, very high or very low pH values may result in an impaired invertebrate assemblage comprised predominantly of tolerant organisms. Field measurements indicated adequate pH values in the biologically impaired segments of Accotink Creek (Section 3.1.5). There have been no observed exceedances of the water quality criterion for pH. Therefore, pH does not appear to be adversely impacting the benthic community in Accotink Creek, and is thus classified as a non-stressor.

4.1.2 Temperature and Dissolved Oxygen

Benthic invertebrates and other aquatic organisms require a suitable range of temperature and dissolved oxygen conditions to survive in rivers or streams. High instream temperature values may result in an impaired invertebrate assemblage composed predominantly of pollution-tolerant organisms. Decreases in instream dissolved oxygen levels can result in oxygen depletion or anoxia, which adversely impact the stream's benthic community. Based on grab and continuous measurements for temperature and dissolved oxygen, data indicated no exceedance of DEQ criteria. In addition, daily fluctuations observed in continuous measurements of dissolved oxygen and temperatures in Accotink Creek were revealed to be small (Section 3.1.5). For this reason, temperature and dissolved oxygen are considered non-stressors to the benthic macroinvertebrate community of Accotink Creek.

4.1.3 Instream Heavy Metals

All available dissolved metals data (aluminum, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc) were below the acute or chronic dissolved freshwater criteria specified in Virginia's aquatic life use standards (Section 3.1.6). Therefore, metals do not appear to be a stressor affecting the benthic macroinvertebrates in Accotink Creek.

4.2 Possible Stressors

4.2.1 Nutrients (Nitrogen, Phosphorus)

High ammonia and nitrate levels in combination with high phosphorus levels generally stimulate algal growth, which may result in eutrophic conditions, high organic loading, and decreased dissolved oxygen. These conditions affect benthic macroinvertebrates present in the stream. The total ammonia concentrations along Accotink Creek were generally low and did not exceed the DEQ criterion (Section 3.1.5). Total ammonia is therefore not considered a stressor. Total phosphorus and total nitrogen observed along the impaired segment of Accotink Creek (**Table 4-2**) were close to or exceeded various published nutrient screening values (**Table 4-3**), and are therefore considered a possible stressor. Due to the fact that biologists' field notes (Section 3.1.2) did not indicate the presence of any algal growth in the stream and DO levels in Accotink Creek meet water quality criteria, nutrients are not considered a most probable stressor in the impaired segment of the Accotink Creek watershed.

Table 4-2: Accotink Creek Nutrient Data - 1995 to Present (All Stations)

	Total Phosphorus (mg/L)	Total Nitrogen (mg/L) Measured	Total Nitrogen (mg/L) Calculated	Total Kjeldahl Nitrogen (mg/L)
Median	0.04	1.04	1.19	0.50
Average	0.05	1.05	1.86	0.64

Table 4-3: Various Published Screening Values for Nutrients

Source	Total Phosphorus (mg/L)	Total Nitrogen (mg/L) Measured	Total Nitrogen (mg/L) Calculated	Total Kjeldahl Nitrogen (mg/L)
Academic Advisory Committee(AAC) Literature Review (2006) EPAs Nutrient Threshold Recommendations - Piedmont Ecoregion	0.03	0.615	0.411	0.23
AAC Literature Review (2006) EPAs Nutrient Threshold Recommendations - Northern Piedmont Ecoregion	0.04	2.225	1.295	0.30
AAC Literature Review (2006) EPAs Nutrient Threshold Recommendations - Aggregated by Ecoregion	0.04	0.69	N/A	N/A
AAC 2008 Report - Nutrient Criteria for Wadeable Streams Critical Value Screening Level	0.40	2.60	N/A	N/A
USGS National Background Levels[1]	0.10	1.00	N/A	N/A

1. U.S. Geological Circular 1225--The Quality of Our Nation's Waters-Nutrients and Pesticides

4.2.2 Toxicity

In-stream toxicity testing by EPA's Region 3 Laboratory at station 1AACO004.84 indicated adverse effects on fathead minnow survival and biomass, and was statistically different from that of control samples. In the professional judgment of the EPA Region 3 Laboratory, the results "were probably biologically significant." EPA emphasized that the results are qualitative in nature, and should be compared with other water quality data collected at this site to determine the causes of toxicity. The effects of water samples from 1AACO006.10 on fathead minnow survival were statistically different from lab samples, but there was no significant effect on minnow biomass (Section 3.1.10). Biologists concluded that these results "may or may not be indicative of a toxic effect." Based on the EPA toxicity test results, toxicity is therefore considered to be a possible stressor in the impaired segments of Accotink Creek.

4.2.3 Metals and Organic Contaminants in Fish Tissue

DEQ collected fish tissue samples at multiple monitoring stations in the Accotink Creek watershed (Section 3.1.9). DEQ analyzed the fish tissue samples for PAHs, PCBs and other halogenated organics, and metals. The results were compared to fish tissue screening values developed by DEQ. Based on DEQ analysis, measurements of heptachlor epoxide, total PCBs, dieldrin, total chlordane, mercury, and arsenic exceeded the screening values for fish tissue. These contaminants may be adversely affecting the benthic community and, therefore, are identified as possible stressors. It should be noted that the tidal portion of Accotink Creek is listed as impaired for not meeting the fish consumption use due to elevated levels of PCBs in fish tissue. TMDLs have been completed for the PCB impairment (Potomac River PCB TMDL, 2007).

4.3 Most Probable Stressors

4.3.1 Stormwater Runoff and Sedimentation

DEQ field biologists noted that excessive sedimentation, generated within the stream channel by urban nonpoint and storm sewer runoff, was degrading the habitat and potentially inhibiting the health of the aquatic community in Accotink Creek. Excess sediment can fill the pores in gravel and cobble substrate, eliminating macroinvertebrate habitat and resulting in loss of pollution-sensitive taxa. Sediment is supported as a stressor in Accotink Creek through (1) the decreased total number of taxa observed, (2) the increase in pollution-tolerant species, (3) the decrease in % scrapers in the watershed; (4) the poor scores for habitat metrics such as epifaunal substrate, bank stability, embeddedness, riparian vegetation, and sediment deposition, (5) the high runoff concentrations of TSS, and (6) the anecdotal evidence of localized in-stream erosion and downstream sediment deposition.

As runoff enters Accotink Creek during storm events, increased sediment loads from in-stream sources (e.g., bank erosion) are generated, causing habitat degradation for aquatic life (e.g., siltation, scour, over-widening of stream channel) and washout of biota. As stated in Section 3.1.2, overall, habitat assessment scores from 2006-2008 were generally low at all stations on Accotink Creek (scores ranged between 91 and 144 with an average score of 118). Scores for habitat metrics such as epifaunal substrate, bank stability, embeddedness, riparian vegetation and sediment deposition were consistently low for the stations on the impaired segment of Accotink Creek (**Figure 3-9**) and provide further evidence that sediment is having significant impacts on aquatic life.

In addition to impacting aquatic life, stormwater runoff has drastically modified the hydrologic characteristics of Accotink Creek. Based on calculations using Fairfax County land use data, approximately 73% of the watershed is developed. According to the watershed management plan for the City of Fairfax (part of which is within the Accotink Creek watershed), a flow frequency analysis showed that the frequency of high stream flow events increased as the amount of impervious surface within the watershed increased (City of Fairfax, 2005). These findings are consistent with other studies done to assess the impact of impervious surfaces on stream hydrology, as explained in Appendix C. Due to high levels of impervious surfaces throughout the watershed, the Accotink Creek watershed is characterized by a very flashy hydrology, with high peak flows during storm events and reduced base-flows during dry weather conditions. Assessment of the stream indicated that altered hydrology has led to a scoured, eroded stream, with a higher than expected median particle size in the substrate of the upper reaches of the impairment. Fine sediments have been transported out of the upstream reach of Accotink Creek and are being deposited downstream close to the tidal boundary. Consequently, the habitat assessment scores indicate that sedimentation and sediment carried by stormwater runoff are the most probable stressors for the benthic macroinvertebrates in the Accotink Creek watershed.

4.3.2 Link between Stormwater Runoff and Stream Sediment Loads

Urbanization has increased the levels of effective imperviousness within the Accotink Creek watershed. This has led to decreased infiltration and increased surface runoff that is conveyed directly to the closest receiving stream during storm events. As large rates of surface runoff enter the stream, the stream bank and stream bed begin to erode and become more unstable. The result is a degraded stream, characterized by steep, eroded banks and scoured river beds in the upstream reaches, and silted riverbeds in the downstream segments that adversely alters the habitat of benthic macroinvertebrates and impairs aquatic life.

The Accotink Creek sediment rating curve (**Figure 4-1**) demonstrates that there is a very strong relationship between stream flow and stream sediment loads. The sediment rating curve approach uses the inherent relationship between flow and sediments to develop correlations between stream flow and total suspended solids (TSS) observations. These correlations characterize sediment loads at different flow regimes and display the relationship between stream flow and sediment loading capacity. The Accotink Creek sediment rating curve was developed using concurrently collected flow and sediment data at USGS Station 01654000 and DEQ water quality station 1AACO014.57. A total of 84 concurrent observations of sediment and flow spanning the period of 1993 to 2007 were used to develop the rating curve. Appendix C discusses the relationships between impervious cover, stream flow, and sediment within the Accotink Creek watershed in greater detail.

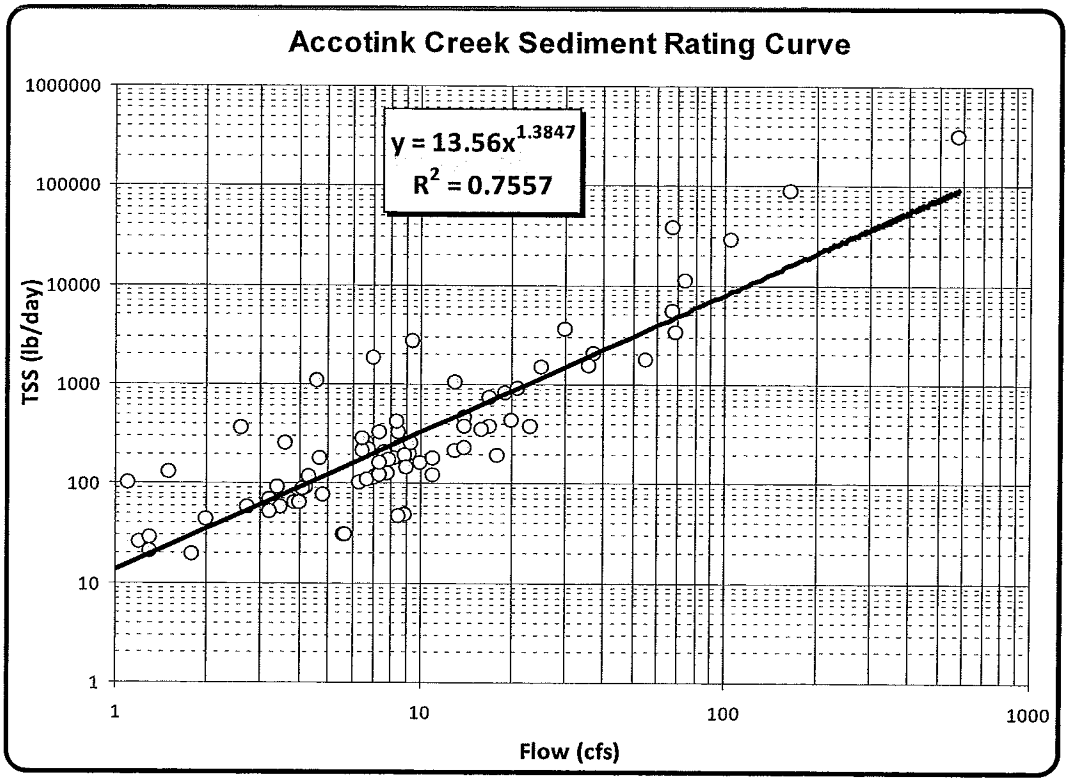

Figure 4-1: Accotink Creek Sediment Rating Curve

4.4 Stressor Identification Summary

The data and analysis presented in this report indicate that pH, dissolved oxygen, temperature, and instream heavy metals in the biologically impaired segments of Accotink Creek were adequate to support a healthy invertebrate community, and were not stressors contributing to the benthic impairments.

Nutrients (nitrogen and phosphorus) were categorized as possible stressors because nutrient concentrations observed along the impaired segment of Accotink Creek were close to or exceeded various published screening values. However, nutrients were not classified as a probable stressor because of the lack of algal growth and the adequate DO levels within the stream.

Toxicity was classified as a possible stressor because DEQ data suggests the presence of toxic pollutants in the impaired segments of Accotink Creek. This is supported by the presence of contaminants in fish tissue, and the results of the chronic toxicity tests on fathead minnows. Therefore, toxicity was identified as a possible stressor. The tidal portion of Accotink Creek is listed as impaired for not meeting the fish consumption use due to elevated levels of PCBs in fish tissue, and a TMDL has been completed for this impairment (Potomac PCB TMDL, approved 2007).

Based on the evidence and data discussed in the preceding sections, sedimentation caused by excessive stormwater runoff has been identified as the primary stressor impacting benthic invertebrates in the biologically impaired segments of Accotink Creek. Habitat scores indicated decreased habitat quality in the impaired segment due to sedimentation and increased runoff from the surrounding urban environment. In addition to impacting aquatic life, stormwater runoff has drastically modified the hydrological characteristics of Accotink Creek as a result of increased urbanization and development. The watershed is characterized by a very flashy hydrology, caused by large rates of stormwater runoff and increased flow velocity.

5.0 TMDL Endpoint Identification

Sedimentation caused by excessive stormwater runoff has been identified as the primary stressor impacting aquatic life in the biologically impaired segments of Accotink Creek. TMDL development requires the determination of endpoints, or water quality targets, for the impaired waterbody. The TMDL endpoint represents the stream condition at which the impaired waterbody would meet water quality standards. Endpoints are normally expressed as the numeric water quality criteria for the pollutant causing the impairment. Compliance with numeric water quality criteria, such as a maximum allowable pollutant concentration, is expected to achieve full use support for the waterbody.

The TMDL for Accotink Creek utilizes a "surrogate" approach in place of the traditional "pollutant of concern" approach to TMDL development. In this TMDL, reductions for a surrogate (stormwater runoff) are established to achieve the necessary reductions for the pollutant of concern (sediment). Under this approach, the TMDL is expressed as the greatest rate of stormwater runoff Accotink Creek can receive without violating the stream's aquatic life criteria. Use of this surrogate approach is appropriate because the pollutant (i.e., sediment) load in Accotink Creek is a function of the amount of stormwater runoff generated within the Accotink Creek watershed. As explained in Section 4.3.2 and Appendix C, the relationship between stormwater runoff and sediment loads in Accotink Creek is especially strong. There are no known wastewater or non-stormwater related discharges contributing to the impairments, so the stormwater runoff surrogate effectively represents the pollutant of concern. In addition, as mentioned in Section 3.3, recommendations from EPA's "Evaluation of Receiving Water Improvements from Stream Restoration, Accotink Creek, Fairfax City, VA," emphasize that a reduction of stormwater runoff and its associated pollutants of concern is needed to achieve improved biological outcomes in the watershed. The study therefore recommends that wet weather flow controls (i.e., stormwater BMPs) be strategically located in the watershed to reduce and delay stormwater discharges to the stream. These recommendations further support EPA's decision to address the benthic impairments in Accotink Creek by using stormwater runoff as a surrogate for sediment.

Using this surrogate approach, reductions in stormwater runoff will achieve the necessary reductions in the delivery and transport of sediment within Accotink Creek. Thus, controlling stormwater runoff as a surrogate for sediment will mitigate the impact of sediment on aquatic life by reducing degradation to existing benthic habitat. As a secondary benefit, a reduction in stormwater runoff will also address the physical impacts of stream channelization, channel erosion, scour and incision caused by excessive runoff, and may also help restore diminished base flow (i.e., increase groundwater recharge).

5.1 Urban Stormwater Runoff as an Endpoint

This TMDL uses a reference, or attainment, stream approach for developing the TMDL endpoint. Under this approach, hydrologic targets for Accotink Creek are based on non-impaired stream data where the aquatic life criteria are currently met as determined through DEQ benthic macroinvertebrate monitoring. Flow duration curves (FDCs) were developed to identify appropriate hydrologic endpoints. FDCs depict the average percentage of time that specific daily flows are equaled or exceeded at sites where continuous records of daily flow are available.

FDCs are cumulative frequency curves of flow quantities without regard to chronology of occurrence. FDCs are graphs, or tables, constructed from a set of flow measurements made over a given interval of time, ranked from largest to smallest value, with a corresponding percentage of days for which the flow value was equaled or exceeded.

FDCs have been widely used for quantifying and studying the effects of urbanization on streams since they reflect changes in a watershed's hydrologic characteristics and can be constructed using the type of flow data that is most readily available. In addition, FDCs are very useful in describing the hydrologic conditions of a stream/watershed because the curves incorporate the full spectrum of flow conditions (very low to very high) that occur in the stream system over a long period of time. FDCs also incorporate any flow variability due to seasonal variations.

In order to make a meaningful comparison, the development and evaluation of FDCs from different USGS gage stations requires the use of a similar period of record. Additionally, a normalized flow rate (flow rate per acre of drainage area) must be used when developing the FDCs from different gage stations. A comparison of FDCs between an impaired stream and appropriate attainment stream(s) can reveal evident flow distribution patterns. When compared to the FDC for an attainment stream, the FDC for a stormwater-impaired stream will generally show higher flow rates during high-flow conditions and lower flow rates during low-flow conditions. This is due to the fact that many stormwater-impaired streams are located in urbanized watersheds, where large amounts of impervious surface increase stormwater runoff and decrease infiltration and groundwater recharge. Thus, when compared to the FDC of a watershed that has not undergone as much development, the FDC of an urbanized watershed tends to have higher "*high flows*" during storm conditions, and lower "*low flows*" during base flow conditions.

The increased predominance of high-flow events in stormwater-impaired watersheds creates the potential for increased stormwater pollutant loadings, increased scouring and stream bank erosion events, and the possible displacement of biota from within the system. In addition, the reduction in stream base flow revealed by the FDC can create a potential loss of habitat during low-flow conditions. Therefore, the selection of appropriate attainment (non-impaired) stream(s) is a critical step when using the FDC approach to establish an appropriate TMDL endpoint.

5.2 Attainment Streams

Under the attainment stream approach, the stormwater TMDL endpoint for an impaired stream is established based on conditions in a similar, but non-impaired attainment stream(s). For benthic impairments caused by excessive stormwater runoff, the TMDL endpoint is the stormwater rate in the attainment stream(s).

The following criteria were used to identify attainment streams that were used to develop the Accotink Creek stormwater TMDL:

- Existing DEQ (or other DEQ-approved, quality assured) biological monitoring data indicating that the aquatic life use, as measured by the health of the benthic macroinvertebrate community, is being fully supported. This criterion is important because it ensures that the flow rates obtained from attainment streams – which will be used to develop the TMDL endpoint – are representative of non-impaired benthic conditions.

- Existing USGS Gage Station located in close proximity to a DEQ biological monitoring station. To develop FDCs for unimpaired waters, the USGS Gage Station must have a daily flow record for a multi-year period that occurred during the same time frame that the biological data was collected. These criteria are important because they insure that the biological data was collected concurrently with the flow data used to develop the TMDL endpoint for the Accotink Creek watershed.
- DEQ biological monitoring station is located in either the Piedmont or Northern Piedmont eco-region. This criterion is important because it ensures that data from the attainment stream is within the same eco-regions as the Accotink Creek watershed.
- Stream orders and drainage areas at the USGS Gage Station of the attainment stream(s) need to be similar in magnitude to the drainage area of Accotink Creek. Stream order is a measure of the position of a stream in a hierarchical tributary network. Stream order is an important characteristic in watershed hydrology affecting travel time, flow, instream processes, and sediment transport. The Accotink Creek drainage area at USGS Gage Station 01654000 is 23.9 mi^2 (**Table 5-1**) and approximately 51mi^2 at the outlet of the watershed.

Based on these criteria, two attainment streams were identified: Catoctin Creek* and Buffalo Creek (**Figure 5-1**). Rather than using data from one non-impaired stream to develop an attainment FDC, it was deemed more appropriate to use data from two attainment streams to develop a composite FDC that combines the flow distribution values for Catoctin Creek and Buffalo Creek. Development of a composite FDC to represent non-impaired flow conditions was determined to be appropriate because it represents the

* Although the North Fork and South Fork of Catoctin Creek were listed as impaired on Virginia's 2008 303(d) List of Impaired waters, the lower mainstem of Catoctin Creek (where the USGS stream gauge is located) is not impaired. Further, neither the North Fork (originally listed as impaired in 2008) nor the South Fork (originally listed as impaired in 2004) of Catoctin Creek were impaired for the majority of the 20-year period of record (Nov. 1989-Nov. 2009) for which flow data was obtained to develop the TMDL. For these reasons, Catoctin Creek was considered a viable attainment stream

average values of the flow data collected from multiple attainment streams, thereby creating a more robust attainment FDC that accounts for a broader range of conditions, including eco-region, soils, slope, stream morphology and land-use. A composite FDC reduces the uncertainty associated with using an FDC from a single attainment stream and was therefore used to estimate the stormwater TMDL endpoint.

Table 5-1 presents summary information on the eco-region, flow data availability, and drainage areas for the USGS gage stations in the Accotink Creek, Buffalo Creek, and Catoctin Creek watersheds. **Table 5-2** presents a comparison of land use distributions in the Accotink Creek, Buffalo Creek, and Catoctin Creek watersheds based upon USGS National Land Cover Data (NLCD) (USGS, 2001; USGS, 2006). **Table 5-3** presents a comparison of the Hydrologic Soil Groups in the Accotink Creek, Buffalo Creek, and Catoctin Creek watersheds based on data from the USDA NRCS SSURGO Database (NRCS, 2006).

Table 5-1: Attainment Streams and Accotink Creek

Stream Name	Eco-region	USGS Station	Period of Flow Record	Drainage Area at the USGS Station (mi^2)
Buffalo Creek	Piedmont	02039000	1946-2009	69.6
Catoctin Creek	Northern Piedmont	01638480	1971-2009	89.5
Accotink Creek	Northern Piedmont, Piedmont, Southeastern Plains	01654000	1947-2009	23.9

Table 5-2: Accotink Creek and Attainment Streams Land Use Comparison (NLCD)

Land Use	Accotink Creek (NLCD 2006)	Buffalo Creek (NLCD 2006)	Catoctin Creek (NLCD 2001)
Water/Wetlands	5%	3%	1%
Urban	66%	2%	7%
Agriculture	< 1%	25%	61%
Forest	29%	70%	31%
Total	**100%**	**100%**	**100%**

* To make a meaningful comparison, this table presents NLCD land use data from all three watersheds. As a result, the Accotink Creek land use percentages provided in this table are slightly different than those provided in Table 2-4 and Section 6, which are based on more detailed Fairfax County land use data.

Table 5-3: Accotink Creek and Attainment Streams Soil Hydrologic Groups Comparison			
Soil Hydrologic Group	Accotink Creek	Buffalo Creek	Catoctin Creek
B	12.4%	52.9%	69.7%
C	10.9%	34.8%	20.6%
D	71.3%	3.1%	9.2%
C/D	-	1.7%	-
B/D	-	5.5%	-
Blank	5.4%	2.1%	0.5%
Total	**100%**	**100%**	**100%**

* (Blank) signifies urban land, pits and water, which do not have soil hydrologic group associations

Table 5-4 presents the watershed slopes for the Accotink Creek, Catoctin Creek, and Buffalo Creek watersheds. Watershed slope is often used as an indicator of the peak discharge in a watershed, and reflects the rate of change of elevation with respect to distance along the principal flow path. The watershed slope affects the timing of runoff, but it also affects the amount of infiltration. The greater the slope, the lower is the infiltration rate. In general, the steeper the slope and the steeper the drainage channels, the quicker the flow response and the higher the peak discharges. A general classification of stream gradient categorizes streams with flat gradients as having a slope between 0 to 3 percent, moderate gradients with slopes from 3-8 percent, and steep gradients with slopes greater than 8 percent (USDA, 1973). All three watersheds fall within the flat gradient classification. Thus, the watershed slopes presented in **Table 5-4** are comparable and further support the use of Catoctin Creek and Buffalo creek as attainment streams.

Table 5-4. Slope for Accotink Creek, Buffalo Creek, and Catoctin Creek				
Watershed	**Highest Stream Elevation (m)**	**Lowest Stream Elevation (m)**	**Stream Length (m)**	**Slope**
Accotink Creek	131	3	33,700	0.38%
Catoctin Creek	348	65	48,000	0.59%
Buffalo Creek	216	92	39,100	0.32%

Figure 5-1 displays the locations of the attainment streams along with the location of the Accotink Creek watershed. **Figure 5-2** displays the location of the monitoring stations within the Buffalo Creek Watershed. **Figure 5-3** displays the location of the monitoring stations within the Catoctin Creek Watershed.

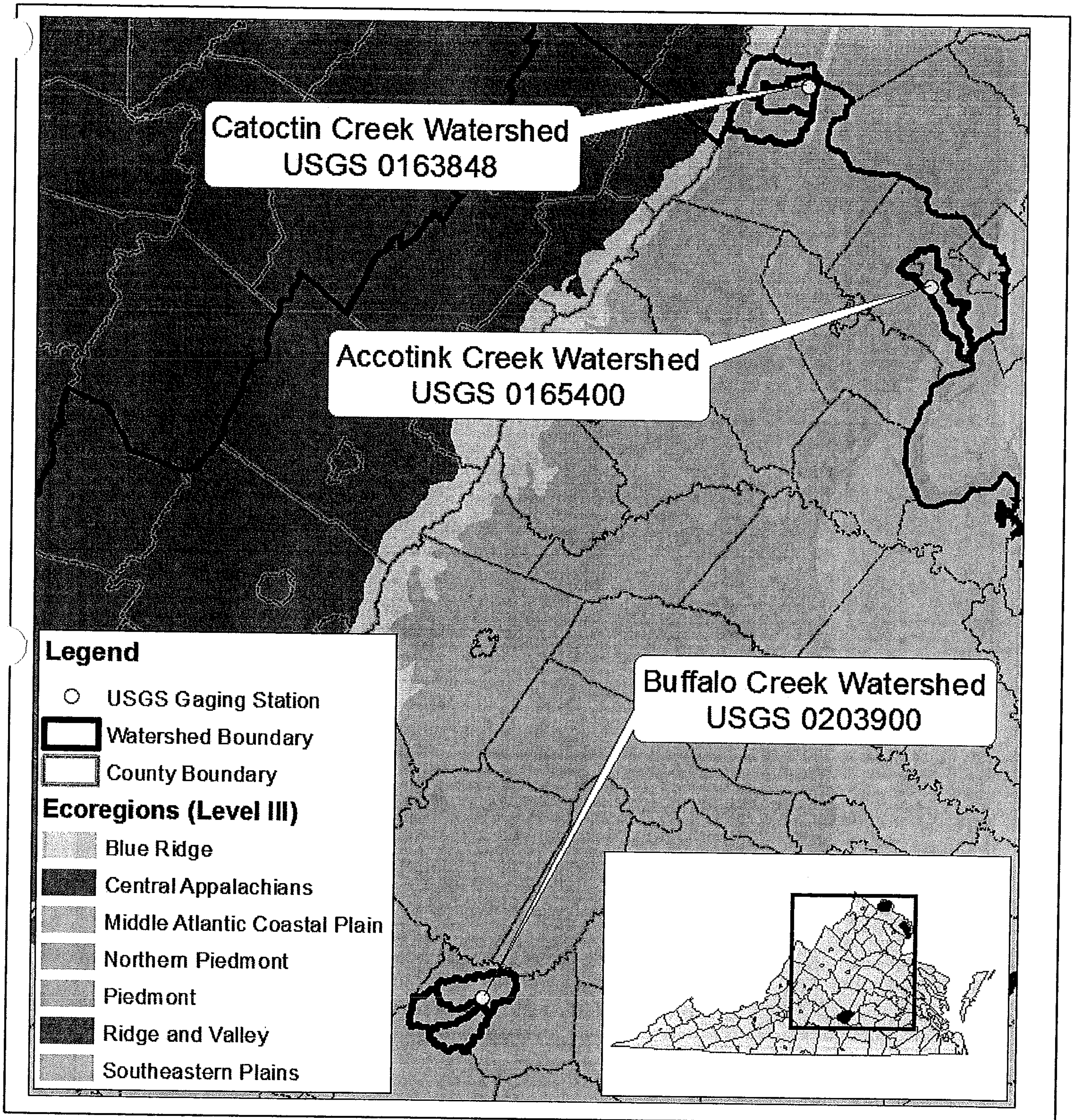

Figure 5-1: Accotink Creek, Catoctin Creek, and Buffalo Creek Watersheds

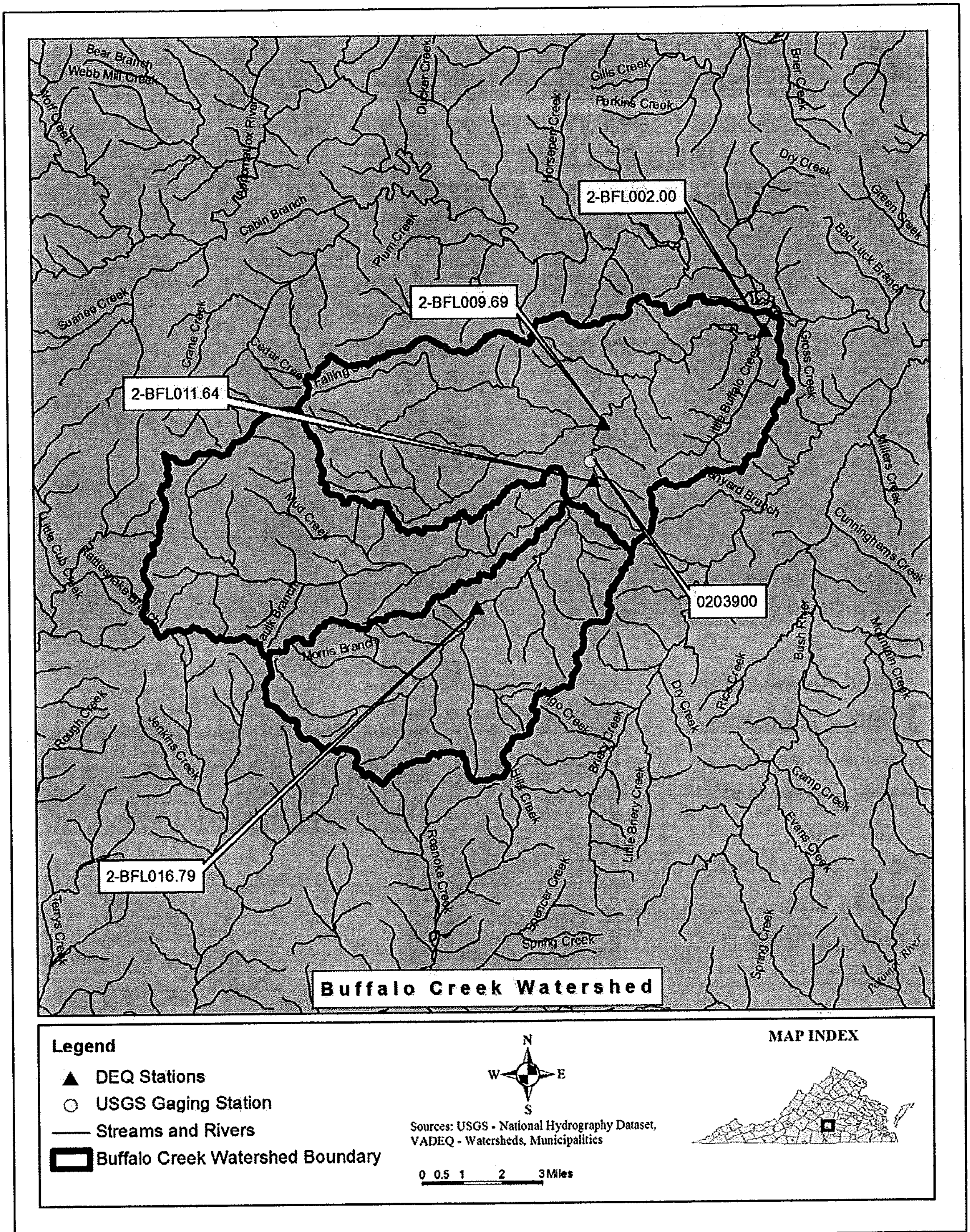

Figure 5-2: Buffalo Creek Watershed and Monitoring Stations

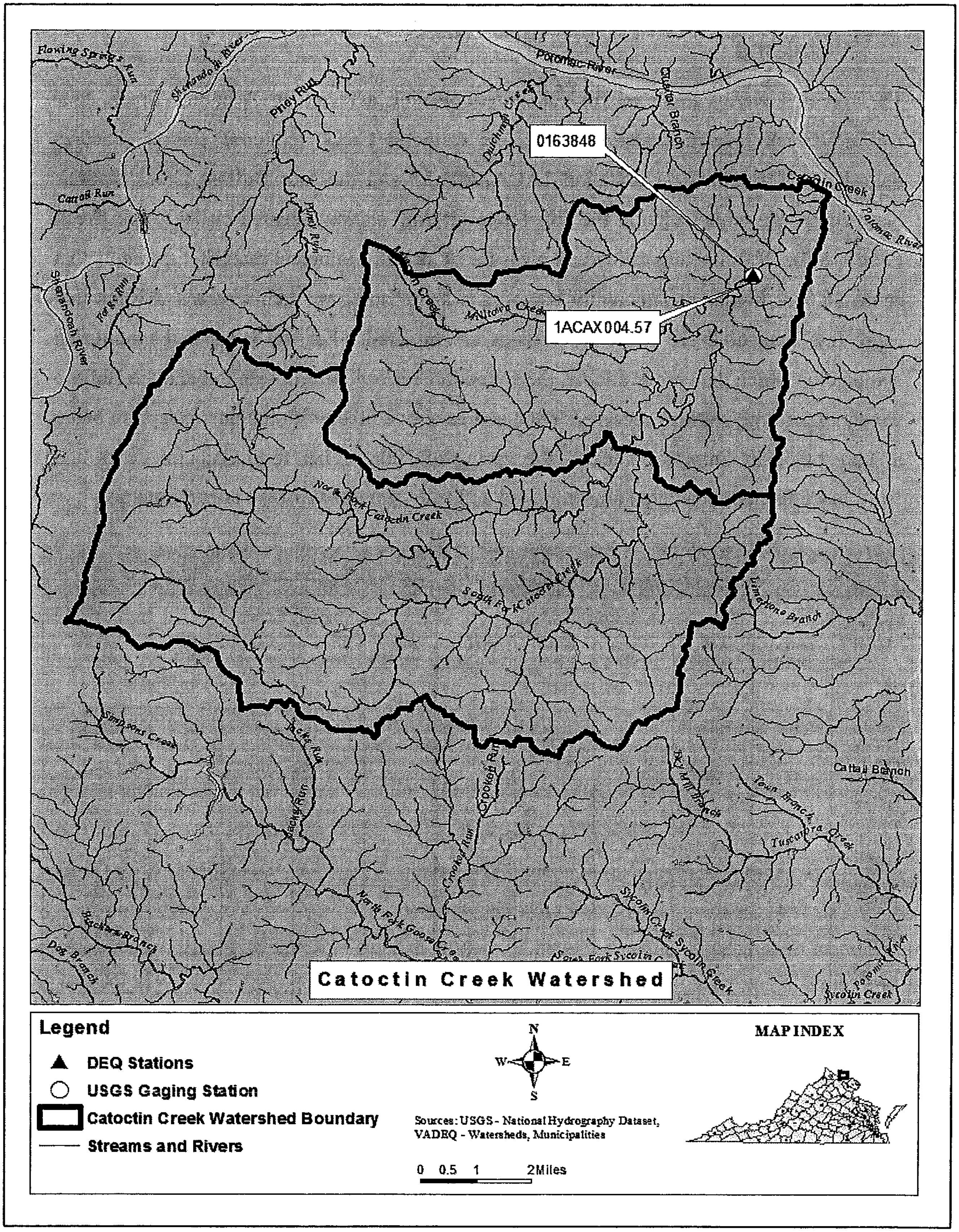

Figure 5-3: Catoctin Creek Watershed and Monitoring Stations

5.2.1 Biomonitoring Data for Accotink Creek and the Attainment Streams

VSCI scores were calculated for five biomonitoring stations on Accotink Creek, four Buffalo Creek reference stations, and one Catoctin Creek reference station. Scores recorded at Catoctin Creek Station 1ACAX004.57 and the four Buffalo Creek stations were compared with scores at the five biomonitoring stations located on Accotink Creek (**Table 5-5**). VSCI scores provide a measure of stream biological integrity. Streams that score 60.0 or higher are generally considered to be non-impaired, whereas streams that score less than 60.0 are generally considered impaired. For the years and monitoring stations for which data are available, the Catoctin Creek monitoring station and the Buffalo Creek monitoring stations received VSCI scores above 60.0, with the one exception being a score of 55 in Catoctin Creek in the Spring of 2003. Therefore, Catoctin Creek and Buffalo Creek are considered non-impaired and fully supportive of the aquatic life use.

Table 5-5: Biomonitoring VSCI Scores for Accotink, Buffalo, and Catoctin Creeks*

Collection Period	Accotink Creek					Buffalo Creek				Catoctin Creek
	1AACO 002.50	1AACO 006.10	1AACO 009.14	1AACO 014.57	1ALOE 001.99	2-BFL 002.00	2-BFL 009.69	2-BFL 011.64	2-BFL 016.79	1ACAX 004.57**
Fall 1994		38.3								70.5
Spring 1995		38.9								73.1
Fall 1995		30.6								66.2
Spring 1996		38.2								67.0
Fall 1996		28.3								63.1
Spring 1997										72.8
Fall 1997										75.5
Spring 1998										74.7
Fall 1998										69.7
Spring 1999										74.0
Fall 1999										71.1
Spring 2000										71.7
Fall 2000										68.5
Spring 2001										69.6

Table 5-5: Biomonitoring VSCI Scores for Accotink, Buffalo, and Catoctin Creeks*

Collection Period	Accotink Creek					Buffalo Creek				Catoctin Creek
	1AACO 002.50	1AACO 006.10	1AACO 009.14	1AACO 014.57	1ALOE 001.99	2-BFL 002.00	2-BFL 009.69	2-BFL 011.64	2-BFL 016.79	1ACAX 004.57**
Fall 2001									67.1	
Spring 2002									63.5	75.48
Fall 2002									69.0	68.74
Spring 2003										54.99
Fall 2003										66.7
Spring 2005										
Fall 2005						78.2	77.4			
Spring 2006	35.3	24.3			29.48	61.0				
Fall 2006	26.6	41.9			24.52	80.0	81.7			
Spring 2007	33.5	36.6		31.6						
Fall 2007	28.3	29.7		30.9						
Spring 2008		25.7	22.8					70.6		61.4
Fall 2008		35.9	30.7					68.8		

* Blank cells indicate dates for which no VSCI score was calculated
** The DEQ biological monitoring station and the USGS gage station are co-located.

5.3 Development of the Flow Duration Curves

A FDC was developed for Accotink Creek (impaired stream) and a composite FDC was developed for the attainment streams (Buffalo Creek and Catoctin Creek). In order to compare the resulting FDCs and identify an appropriate stormwater target, the FDCs must be developed using a similar period of record. In addition, the period of flow record should be sufficient to cover all ranges of hydrologic regime encompassing wet, normal, and dry hydrologic years. Based on the period of available biological monitoring data (**Table 5-5**) and streamflow data (**Table 5-1**), use of a 20-year period of record from November, 1989 through November, 2009 was deemed most appropriate to develop the FDCs.

The FDC for Accotink Creek was developed using the following steps:

1. Using the hourly flow rates observed at USGS Station 01654000, calculate the daily average flow rate for each day in the 20-year period of record. (Note: The USGS hourly flow rates used to develop the FDCs in this report are readily available and can be obtained from the USGS website for Virginia Surface-Water Data at: http://waterdata.usgs.gov/va/nwis/sw.)
2. Convert the daily average flow rates at USGS Station 01654000 from cubic feet per second (cfs) to cubic feet per day (ft^3/day). This was done to address the need for the final TMDL allocations to be expressed as daily loads, and was calculated by multiplying the daily average flow value, expressed in cfs, by 86,400 seconds (the total number of seconds in one day).
3. Convert the daily average flow rates (ft^3/day) to daily average unit-area flow rates (ft^3/acre-day). This was done to develop readily comparable FDCs that account for the fact that the total drainage area at the USGS station in Accotink Creek is different from the drainage areas of the USGS stations in Buffalo and Catoctin Creeks (as indicated in **Table 5-1**). To convert the daily average flow rates (ft^3/day) to daily average unit-area flow rates (ft^3/acre-day), the daily average flow rates were divided by the total number of acres draining to USGS Station 01654000 (15,296 acres).
4. Rank the daily average unit-area flow rates from the highest to the lowest, where the highest daily average unit-area flow rate within the 20-year period of record is assigned a ranking of 1, the second-highest daily average unit-area flow rate is assigned a ranking of 2, and so on.
5. For each of the ranked daily average unit-area flow rates, calculate the corresponding probability of exceedance (i.e., the probability that a given daily average unit-area flow rate is equaled or exceeded based upon the 20-year period of record). The probability of exceedance for each of the daily average unit-area flow rates was calculated by dividing the rank of the specific daily flow value by the total number of daily observations in the 20-year period.
6. Plot the Accotink FDC such that the daily average unit-area flow rate is on the Y-axis and the probability of exceedance is on the X-axis.

Using a similar process, the composite FDC for Buffalo Creek and Catoctin Creek was developed using the following steps:

1. Using the hourly flow rates observed at USGS Stations 02039000 (Buffalo Creek) and 01638480 (Catoctin Creek), calculate the daily average flow rate at each station for each day in the 20-year period of record.
2. Convert the daily average flow rates at both USGS stations from cubic feet per second (cfs) to cubic feet per day (ft^3/day).
3. Convert the daily average flow rates (ft^3/day) at both USGS stations to daily average unit-area flow rates (ft^3/acre-day).
4. Rank the daily average unit-area flow rates at both USGS stations from the highest to the lowest.
5. Calculate the average of the ranked daily average unit-area flow rates from both USGS stations to establish a composite of ranked daily average unit-area flow rates. (Note: EPA's decision to use the average value (as opposed to the maximum value) of the ranked daily average unit-area flow rates in Buffalo and Catoctin Creeks provides a MOS to the TMDL, as indicated in Section 6.5.)
6. For each of the ranked composite daily average unit-area flow rates, calculate the corresponding probability of exceedance.
7. Plot the composite attainment FDC such that the daily average unit-area flow rate is on the Y-axis and the probability of exceedance is on the X-axis

The Accotink Creek FDC and the composite FDC are shown in **Figure 5-4**. For informational purposes, the individual FDC's for Catoctin Creek, Buffalo Creek, and the Accotink Creek are presented in **Figure 5-5**. A comparison of the Accotink Creek and non-impaired composite FDC, shown in **Figure 5-4**, indicate that the non-impaired composite FDC exhibits a different hydrologic response when compared to the impaired Accotink Creek FDC. Because the urbanized nature of the Accotink Creek watershed generates greater rates of stormwater during precipitation events, the impaired Accotink FDC is higher than the non-impaired composite FDC at the high-flow range. Alternatively, the non-impaired composite FDC is higher at the low-flow range since the decrease in infiltration in Accotink Creek resulted in lower ground water recharge, thus causing a decrease in stream baseflow.

5.4 Estimation of the Flow Rate Reduction – Target Settings

The composite FDC for the attainment streams (Catoctin Creek and Buffalo Creek) represents flow conditions under which the biologic criteria are currently being met. In order to estimate the stormwater flow reduction needed to address the benthic impairments in Accotink Creek, it is necessary to identify appropriate target flow conditions for TMDL development. A high-flow target value equal to the one-year, 24-hour flow rate and a low-flow target value equal to the 95th percentile flow rate were selected as points along the FDCs useful for setting specific hydrologic targets. The one-year, 24-hour flow rate is the maximum daily average flow rate with a one-year recurrence interval (calculated in Table 5-5), while the 95th percentile flow rate represents a flow condition comparable to the lowest stream flow for seven consecutive days that would be expected to occur once in ten years (7Q10).

Although both low and high-flow targets were established, TMDL allocations were based solely upon the one-year, 24-hour high-flow target. The primary function of a TMDL is to determine and allocate among sources the maximum pollutant loading a waterbody can receive to maintain compliance with the appropriate water quality standard(s). For the Accotink Creek stormwater TMDL, stormwater runoff rates are limited and allocated among sources. This approach works well within the TMDL framework for the high-flow target, where an overall reduction of stormwater runoff is required. However, this approach does not fit particularly well for the low-flow target, where an increase in non-stormwater instream flow is necessary, and increased loading of stormwater runoff is not directly being allocated. EPA believes the restoration of low-flows in Accotink Creek is a secondary result of controlling stormwater runoff rates (high flows) and increasing groundwater recharge. As stormwater runoff rates are controlled through high-flow reductions, the water that eventually reaches the stream is no longer considered stormwater runoff because it is generally routed through the groundwater system and does not reach the stream for a significant amount of time following the precipitation event.

Additionally, the benefit of decreased pollutant loading due to reduced stormwater runoff rates at high flows provides a good fit within the TMDL framework. The same cannot be said of the low-flow target. The low-flow target represents conditions where pollutants are already substantially removed from water the stream receives from groundwater, and thus there are no problematic "pollutants" to allocate.

For these reasons, TMDL allocations were based solely upon the one-year, 24-hour high-flow target. EPA believes that the one-year, 24-hour flow is an appropriate target because:

1) The one-year, 24-hour flow level targets channel forming flow which can directly reduce key channel altering events that damage biota and produce large amounts of sediment from within the stream system;

2) The one-year, 24-hour flow is close to the upper end of the high-flow portion of the FDCs – selecting a target close to the upper end of the curve helps ensure that the implementation measures chosen to meet the target will also reduce the impact of the full range of storms that drive the shape of the rest of the FDCs;

3) Virginia has proposed design specifications for stormwater management measures that are largely based on controlling the one-year, 24-hour storm event.

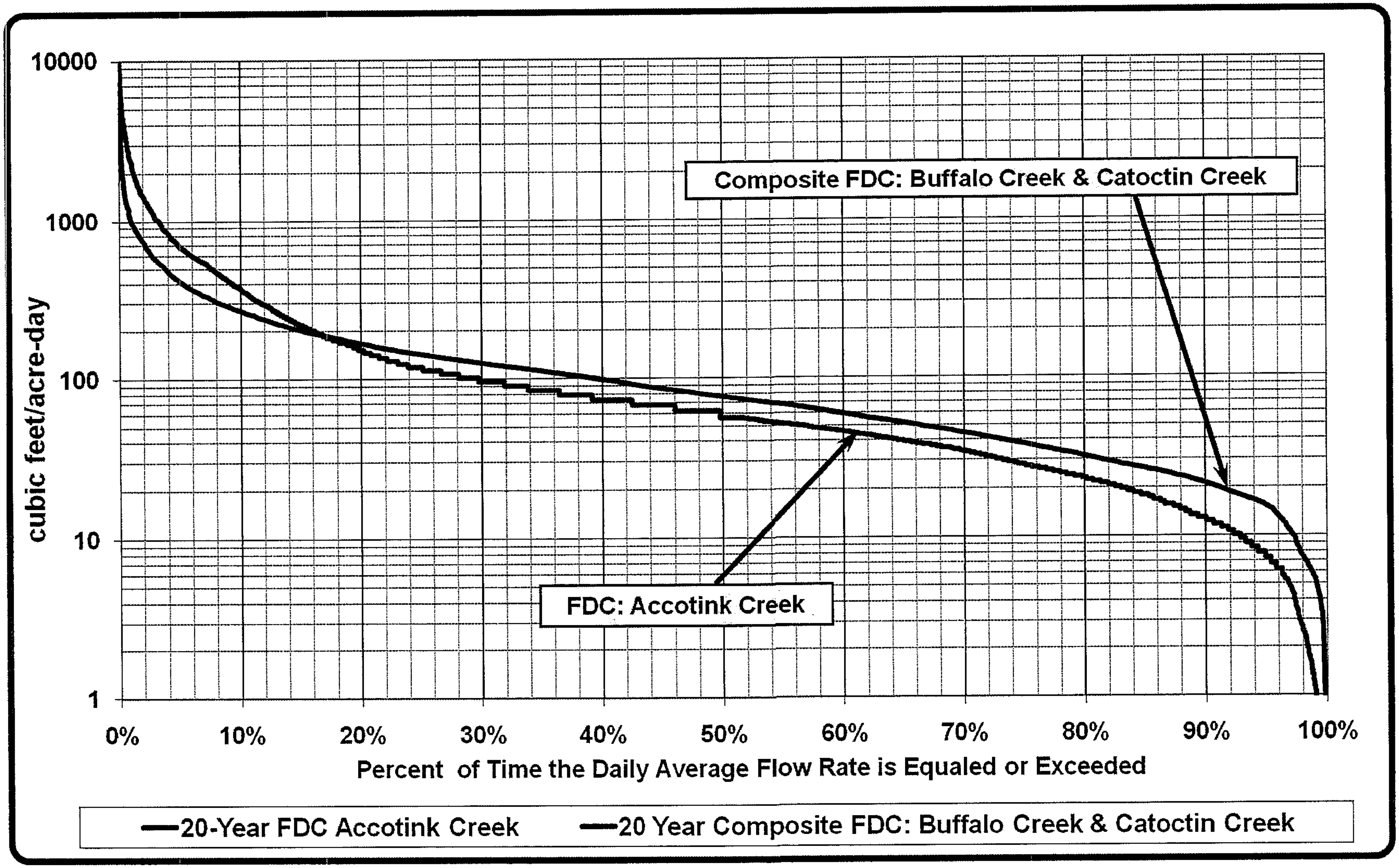

Figure 5-4. Accotink Creek FDC and Composite FDC (Buffalo Creek & Catoctin Creek) using 20-year Flow Record (11/1989 – 11/2009)

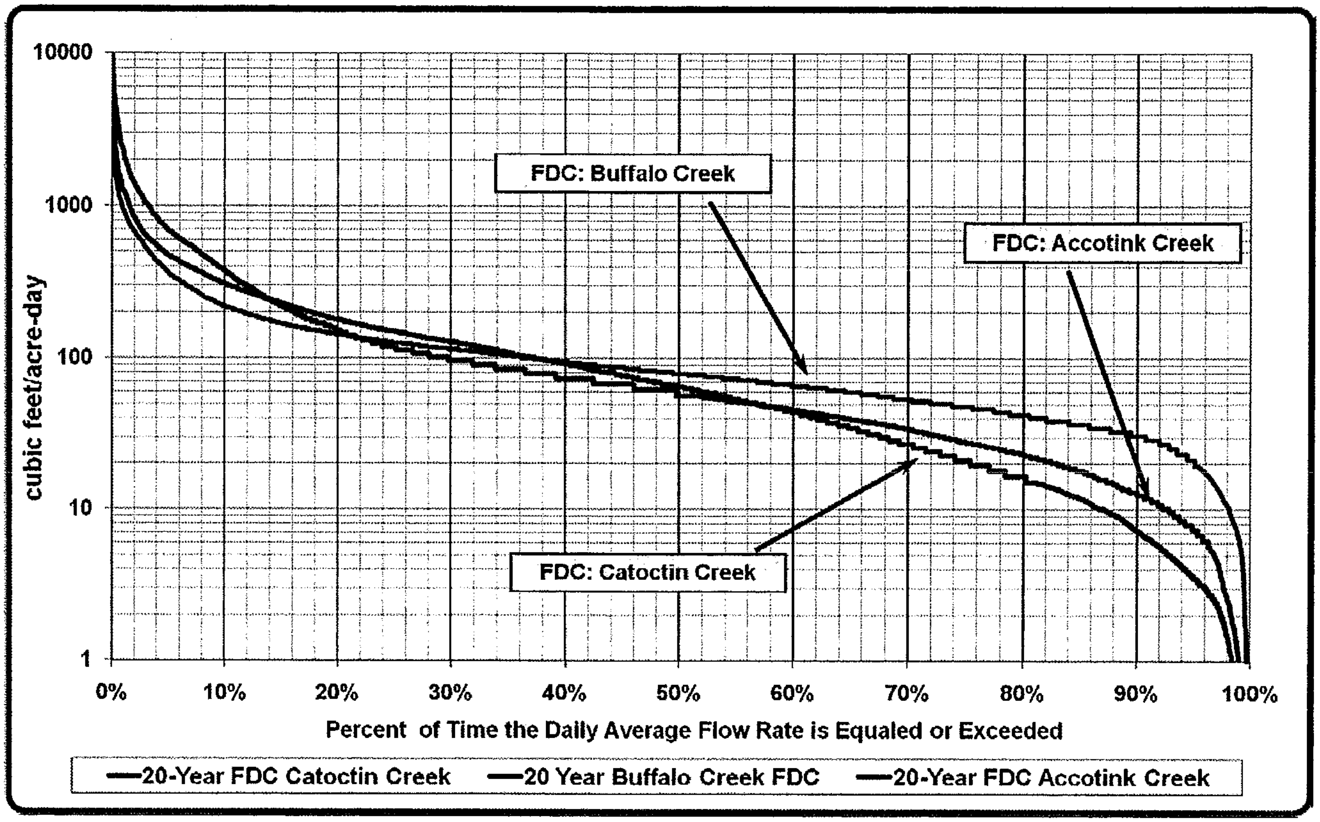

Figure 5-5. Catoctin Creek, Buffalo Creek and Accotink Creek FDCs using 20-year Flow Record (11/1989 – 11/2009)

In the Accotink Creek Watershed, the one-year, 24-hour stormwater flow was estimated at 234 cfs. This value is based upon analysis of flow data from the same 20-year period of record (November 1989 through November 2009) that was used to develop the FDCs for Accotink Creek and the attainment streams. The one-year, 24-hour stormwater flow for Accotink Creek, 234 cfs, was estimated with a standard technique used in high-flow frequency analysis. First, the maximum daily average flow rate that occurred during each year in the 20-year period of record was identified. Next, the maximum daily average flow rates identified for each year were arranged in order of increasing magnitude and assigned an order number "*m*" corresponding to their ranked values. For example, the year with the highest daily average flow rate was assigned an order number "*m*" equal to 1, the year with the second highest daily average flow rate was assigned an order number "*m*" equal to 2, and so forth. Finally, the recurrence interval (T) in years was estimated using the relationship T = n/m where *n* is the number of observations (years in the period of record). **Table 5-6** depicts the high-flow frequency analysis for Accotink Creek and indicates that the one-year, 24-hour flow is 234 cfs.

Table 5-6: Accotink Creek High-Flow Frequency Analysis 1989-2009 Hydrologic Years

Year	24-hour Flow Rate (cfs)	24-hour Flow Rate (ft^3/day)	Rank	Recurrence Interval (years)	Year	24-hour Flow Rate (cfs)	24-hour Flow Rate (ft^3/day)	Rank	Recurrence Interval (years)
2008	2,800	241,920,000	1	20.0	1993	936	80,870,400	11	1.8
2006	1,720	148,608,000	2	10.0	2007	900	77,760,000	12	1.7
1991	1,560	134,784,000	3	6.7	2000	896	77,414,400	13	1.5
1996	1,550	133,920,000	4	5.0	1997	880	76,032,000	14	1.4
1994	1,500	129,600,000	5	4.0	2001	816	70,502,400	15	1.3
2003	1,340	115,776,000	6	3.3	1990	653	56,419,200	16	1.3
2004	1,160	100,224,000	7	2.9	2009	642	55,468,800	17	1.2
1999	1,160	100,224,000	8	2.5	1992	570	49,248,000	18	1.1
1998	985	85,104,000	9	2.2	2002	354	30,585,600	19	1.1
2005	950	82,080,000	10	2.0	**1995**	**234**	**20,217,600**	**20**	**1.0**

EPA regulations require that TMDL allocations be expressed as daily loads. The one-year, 24-hour flow rate of 234 cubic feet per second was therefore converted to 20,217,600 cubic feet per day (234 cfs x 86400 seconds in one day), as indicated in **Table 5-6**. The one-year, 24-hour flow rate in Accotink Creek (20,217,600 ft^3/day) also corresponds to a unit-area flow rate of 1,321.7 ft^3/acre-day. This was calculated by dividing the one-year, 24-hour flow rate (20,217,600 ft^3/day) by the total number of acres draining to USGS Station 01654000 (15,296 acres). When plotted along the Accotink Creek FDC, it is clear that 1,321.7 ft^3/acre-day falls within the high-flow portion (0-10%) of the Accotink FDC. **Figure 5-6** depicts the high-flow portion (0-3%) of the FDCs with the corresponding Accotink Creek one-year, 24-hour flow rate. For informational purposes, **Figure 5-7** depicts the 95th percentile low-flow portion of the FDCs.

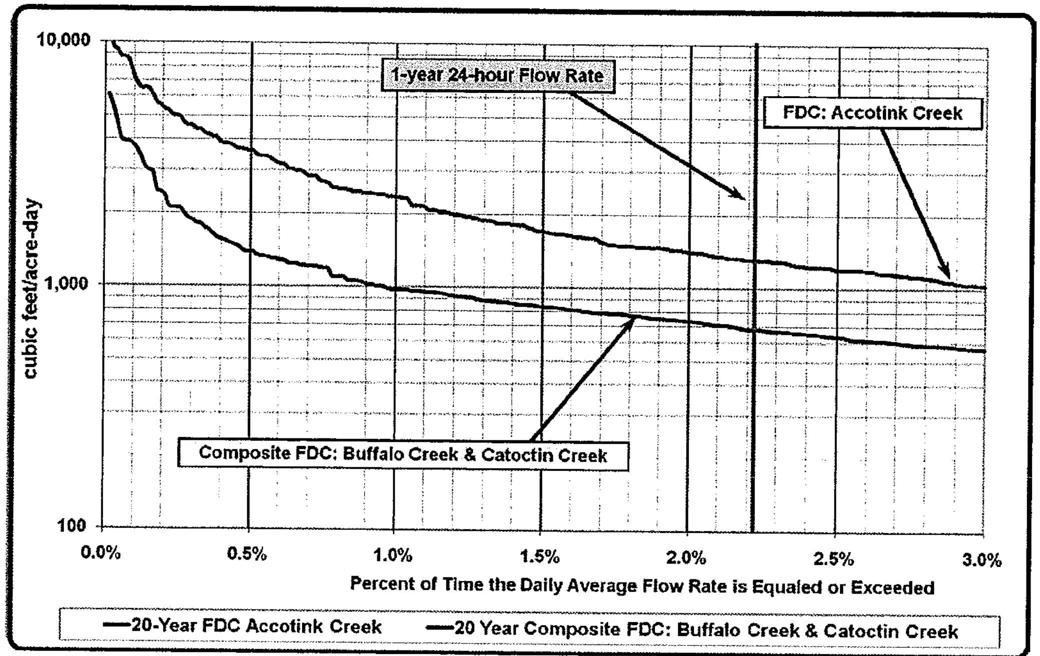

Figure 5-6. Accotink Creek and Composite FDCs with the TMDL One-Year, 24-Hour High-Flow Rate

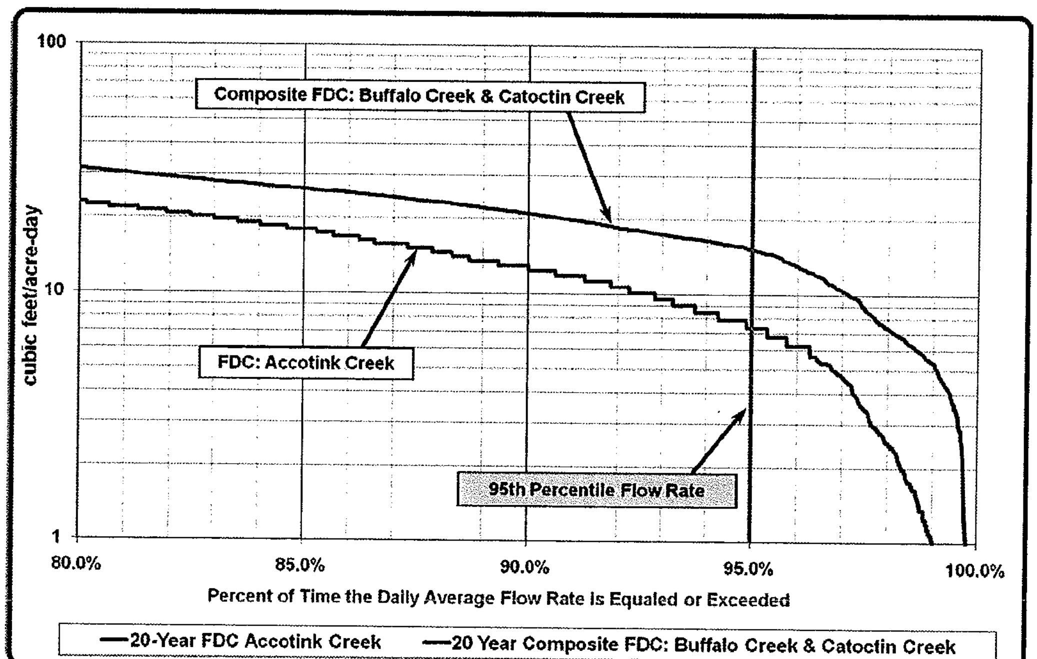

Figure 5-7. Accotink Creek and Composite FDCs with the 95th percentile Low-Flow Rate

Figure 5-6 indicates that the one-year, 24-hour flow unit area flow rate in Accotink Creek of 1,321.7 ft^3/acre-day corresponds to a unit-area flow rate of 681.8 ft^3/acre-day on the composite attainment FDC. This value (681.8 ft^3/acre-day) corresponds to the greatest unit-area flow rate that Accotink Creek can receive during the one-year, 24-hour flow without violating the stream's aquatic life criteria. Since this target flow rate was developed in terms of a unit-area (ft^3/acre-day) it will be applicable to the entire Accotink Creek drainage area.

Table 5-7 summarizes the results of the analysis using the one-year, 24-hour stormwater flow.

Table 5-7: Estimation of Overall TMDL Stormwater Flow Reduction for a one-year, 24- hour flow

Accotink Creek Flow Volume (ft^3)	Accotink Creek Unit-Area Flow Rate (ft^3/acre-day)	Non-impaired Composite Unit-Area Flow Rate (ft^3/acre-day)	Flow Rate Reduction (ft^3/acre-day)	Overall Reduction
20,217,600	1,321.7	681.8	639.9	48.4%

6.0 TMDL Allocation

The overall purpose of developing TMDL allocations is to quantify pollutant load reductions necessary to achieve applicable water quality standards in an impaired waterbody. For the Accotink Creek stormwater TMDL, stormwater runoff was used as a surrogate to address the needed reductions in sediment. As discussed in Section 5.0, a FDC approach was applied to compare stormwater flows from selected non-impaired streams with stormwater flows in the impaired segment of Accotink Creek to identify an appropriate TMDL endpoint. A one-year, 24-hour stormwater flow was selected as an appropriate hydrologic target and was used to estimate the existing stormwater flow rate in Accotink Creek as well as the TMDL endpoint (**Table 5-7**). A reduction of the one-year, 24-hour flow rate in the impaired Accotink Creek watershed to the level of the one-year, 24-hour flow rate in the non-impaired streams is expected to restore the aquatic life use in the Accotink Creek watershed. The TMDL allocations for the Accotink Creek impaired watershed are based on the following equation.

$$TMDL = \sum WLA + \sum LA + MOS$$

where:

TMDL = Total Maximum Daily Load

WLA = Wasteload Allocation

LA = Load Allocation

MOS = Margin of Safety

The WLA represents the total stormwater flow allocated to point sources. The LA represents the total stormwater flow allocated to nonpoint sources. The MOS is a required TMDL element to account for uncertainties in TMDL development. The MOS was implicitly incorporated into this TMDL by using conservative factors in multiple steps of TMDL development, as explained in Section 6.5.

6.1 Basis for TMDL Allocations

The Accotink stormwater TMDL must allocate the overall TMDL endpoint between point sources (WLA) and nonpoint sources (LA). This TMDL was developed using a land-use based allocation approach to calculate existing conditions and to develop WLAs and LAs. One-year, 24-hour stormwater flow rates were used to determine the existing stormwater contribution from all land uses within the Accotink Creek watershed. The existing one-year, 24-hour unit-area stormwater flow rate in Accotink Creek was estimated at 1,321.7 ft^3/acre-day using a 20-year period of record (Section 5.4). Once the existing one-year, 24-hour unit-area stormwater flow rate in Accotink Creek was identified, the rational method was used to calculate the existing-conditions stormwater contribution from each individual land use category in the Accotink Creek watershed. The rational method is the most widely used equation for estimating runoff, and relates the peak discharge (Q, cfs) to the drainage area (A, acres), the rainfall intensity (I, in/hour), and the runoff coefficient (Rc):

$$Q = Rc * I * A$$

The runoff coefficient (Rc) relates the amount of runoff to the amount of precipitation received; in other words it represents the fraction of precipitation that appears as runoff and is expressed as a constant value between zero and one. Runoff coefficients can be determined using the following equation (Schueller, 1987):

$$\text{Runoff Coefficient } (Rc) = 0.05 + 0.9 * \text{Fraction of Imperviousness}$$

This relationship is widely used in hydrologic studies since the percent of imperviousness has been shown as a reasonable predictor of the runoff coefficient. The percent runoff contribution from each land use category was estimated using the rational method along with the measured fraction of imperviousness for each land use category. Because of the linearity of the Rational Method, the use of any rainfall intensity would result in the same distribution of the target flow among all the land use categories. **Table 6-1** presents the percent distribution of the runoff resulting from a 1 inch rainfall. The percent runoff contribution from each land use category was then applied to the unit-area stormwater runoff rate generated by the one-year, 24-hour flow in Accotink Creek (i.e., 1,321.7 ft^3/acre-day).

Table 6-2 outlines the resulting distribution of the one-year, 24-hour flow in Accotink Creek.

Table 6-1: Percent Runoff Contribution from the Land Use Categories Using a One Inch Rainfall

Fairfax County Land Use Type	Acres	Percent Imperviousness*	Runoff Coefficient	Runoff (cfs)	Percent Runoff Contribution
High Density Residential	3,003	32	0.338	1,015.0	12.3%
Medium Density Residential	7,655	14	0.176	1,347.3	16.3%
Institutional	1,464	26	0.284	415.8	5.0%
Industrial	1,949	50	0.500	974.5	11.8%
High Intensity Commercial	757	76	0.734	555.6	6.7%
Low Intensity Commercial	843	58	0.572	482.2	5.8%
Transportation	4,566	59	0.581	2,652.9	32.1%
Estate Residential	383	5	0.095	36.4	0.4%
Golf Course	686	1	0.059	40.5	0.5%
Low Density Residential	3,286	8	0.122	400.9	4.9%
Open Space	5,715	1	0.059	337.2	4.1%
Total	**30,307**			**8,258.2**	**100.0%**

* Based upon Fairfax County Planimetric Land Use Dataset (Fairfax County, 2002)

Table 6-2: Accotink Creek Existing Conditions Unit-Area Flow Rate (one-year, 24-hour flow)

Fairfax County Land Use Type	Acres	Percent Runoff Contribution*	Flow (ft^3/acre-day)
High Density Residential	3,003	12.3%	162.5
Medium Density Residential	7,655	16.3%	215.6
Institutional	1,464	5.0%	66.5
Industrial	1,949	11.8%	156.0
High Intensity Commercial	757	6.7%	88.9
Low Intensity Commercial	843	5.8%	77.2
Transportation	4,566	32.1%	424.6
Estate Residential	383	0.4%	5.8
Golf Course	686	0.5%	6.5
Low Density Residential	3,286	4.9%	64.2
Open Space	5,715	4.1%	54.0
Total	**30,307**	**100.0%**	**1,321.7****

* Calculated in Table 6-1
** Calculated in Section 5.4

The analysis and total acreage presented in **Table 6-1** and **Table 6-2** does not incorporate the Water/Wetland land use category (346 acres, as indicated in **Table 2-4**) since it does not contribute to stormwater runoff. Therefore the total acreage presented in these tables is 30,307 acres (not 30,653 acres, as reported in **Table 2-4**). The percent of imperviousness shown in **Tables 6-1** and **Table 6-2** was based on the Fairfax County Department of Public Works and Environmental Services' planimetric land use data, which describes the pervious and impervious levels within each land use category in the Accotink Creek Watershed (Fairfax County, 2002).

6.2 TMDL Allocations

TMDL WLAs and LAs for the Accotink Creek watershed were developed based upon the existing contribution of stormwater flow from each land use category **(Table 6-2)** and the overall required stormwater flow reduction **(Table 5-7)**. The resulting discharge reductions presented in **Table 6-3** and **Table 6-4** were developed by assigning equal reductions to the existing stormwater flow contribution from all land use categories except for the Open Space land use category.

The entire Accotink Creek watershed is located within the physical boundaries of the MS4 permittees indentified in **Table 2-8**. That said, the LAs presented in **Table 6-3** are based on the assumption that a portion of the existing stormwater flow in the Accotink Creek watershed is generated on lands that do not discharge to a regulated storm sewer system (i.e., lands that drain directly to the nearest receiving stream, or lands that drain to a privately owned/operated storm sewer system). Based upon the best professional judgment of EPA, DCR and an analysis of all available data, EPA conservatively estimates that 10% of the existing stormwater flow in the Accotink Creek watershed does not drain to a regulated storm sewer system. If, in the future, additional data becomes available which indicates that the percentage of stormwater flow from lands not connected to a regulated storm sewer system is higher or lower than 10%, the TMDL can be revised to reflect this information. Based upon EPA's current estimate, 10% of the existing stormwater flow from each land use category was used to calculate the LAs assigned to nonpoint sources in **Table 6-3**.

Table 6-3: Load Allocations for Nonpoint Sources in the Accotink Creek Watershed

	Land Use Category	Acres	Existing Load (ft^3/acre-day)	LA (ft^3/acre-day)	Percent Reduction
Lands not Discharging to an MS4 (10% of existing stormwater flow)	High Density Residential	300.3	16.2	8.05	50.5%
	Medium Density Residential	765.5	21.6	10.68	50.5%
	Institutional	146.4	6.7	3.3	50.5%
	Industrial	194.9	15.6	7.72	50.5%
	High Intensity Commercial	75.7	8.9	4.4	50.5%
	Low Intensity Commercial	84.3	7.7	3.82	50.5%
	Transportation	456.6	42.5	21.03	50.5%
	Estate Residential	38.3	0.6	0.29	50.5%
	Golf Course	68.6	0.6	0.32	50.5%
	Low Density Residential	328.6	6.4	3.18	50.5%
	Open Space	571.5	5.4	5.4	0.0%
	Total	**3,031**	**132.2**	**68.2**	**48.4%**

Since the LAs presented in **Table 6-3** are based on the assumption that stormwater runoff from 10% of the existing stormwater flow in the Accotink Creek watershed does not drain to a regulated storm sewer system, the discharge reductions presented in **Table 6-4** are based on the corresponding assumption that stormwater runoff from 90% of all land uses in the watershed drains to regulated storm sewer systems. Therefore, the existing stormwater flows from 90% of each land use category were used to calculate the existing loads and WLAs assigned to point sources. The total load (613.6 ft^3/acre-day) in **Table 6-4** represents the aggregate WLA for all permitted sources in the watershed, including the individual MS4 permits (indentified in **Table 2-8**), the individual stormwater permits (identified in **Table 2-6**) and the general stormwater permits (identified in **Table 2-7** and **Table 2-9**). **Table 6-4** was disaggregated to provide information about individual contributions from various stormwater permittees in the Accotink Creek watershed, as explained in Section 6.3.

Table 6-4: Land Use Summary for Point Sources in the Accotink Creek Watershed*

	Land Use Category	Acres	Existing Load (ft^3/acre-day)	TMDL Load (ft^3/acre-day)	Percent Reduction
Lands Discharging to an MS4 (90% of existing stormwater flow)	High Density Residential	2,702.7	146.2	72.4	50.5%
	Medium Density Residential	6,889.5	194.1	96.1	50.5%
	Institutional	1,317.6	59.9	29.7	50.5%
	Industrial	1,754.1	140.4	69.5	50.5%
	High Intensity Commercial	681.3	80.0	39.6	50.5%
	Low Intensity Commercial	758.7	69.5	34.4	50.5%
	Transportation	4,109.4	382.1	189.2	50.5%
	Estate Residential	344.7	5.2	2.6	50.5%
	Golf Course	617.4	5.8	2.9	50.5%
	Low Density Residential	2957.4	57.7	28.6	50.5%
	Open Space	5,143.5	48.6	48.6	0.0%
	Total	**27,276**	**1,189.5**	**613.6**	**48.4%**

* This table is presented for informational purposes only. This table does not represent wasteload allocations to specific land uses, and EPA's inclusion of this table should not be construed as requiring an equal reduction of stormwater discharges from all land use categories except Open Space. The WLAs assigned to the MS4 permits represent aggregate loads from all land uses, and it is an assumption of this TMDL that the permitting authority and the permit holder will determine how and at what relative levels to implement reductions among the various land uses to achieve the WLAs.

6.3 WLA Development

In this section, the aggregate WLA (613.6 ft^3/acre-day) presented in **Table 6-4** will be disaggregated so that WLAs are established for stormwater permittees within the Accotink Creek watershed, including general and individual industrial stormwater permits (Section 6.3.1) and MS4 and construction stormwater permits (Section 6.3.2).

6.3.1 WLAs for Industrial Stormwater Permits

There are a total of 23 facilities with individual or general industrial stormwater permits in the Accotink Creek Watershed. Five facilities are covered under individual VPDES permits. In addition, there are 18 facilities (16 industrial facilities and 2 concrete facilities) discharging pursuant to general VPDES permits for industrial stormwater. Aside from the acreage of Shenandoah's Pride Dairy (VAR051100) – which was estimated using GIS location data and imagery – the acreage for each facility (**Table 6-5**) was based upon information provided by each permittee. Eighteen (18) of the stormwater permittees are in Fairfax County, 4 stormwater permittees are in the City of Fairfax, and one stormwater permittee is in the Fort Belvoir Military Reservation.

Table 6-5: Drainage Areas for Industrial Stormwater Permits				
Facility Name	**Permit Number**	**MS4 Area**	**Drainage Area (acres)**	**WLA Reduction of One-Year, 24-Hour Flow**
Industrial Stormwater Individual Permits				
Fairfax Terminal Complex	VA0001872	Fairfax City	106.4	50.5%
Kinder Morgan Southeast Terminals	VA0001945	Fairfax County	17.9	50.5%
Motiva Enterprises LLC - Springfield	VA0001988	Fairfax County	10.9	50.5%
Motiva Enterprises LLC - Fairfax	VA0002283	Fairfax City	4.6	50.5%
Quarles Petroleum - Newington	VA0057380	Fairfax County	3.6	50.5%
Industrial Stormwater General Permits				
Canada Dry - Springfield	VAR050988	Fairfax County	4	50.5%
SICPA Securink Corporation	VAR051042	Fairfax County	7.5	50.5%
Connector Bus Yard	VAR051047	Fairfax County	6.3	50.5%
United Parcel Service	VAR051053	Fairfax County	2	50.5%
US Postal Service - Merrifield	VAR051066	Fairfax County	1.8	50.5%
Fort Belvoir Davison Army Airfield	VAR051080	Fort Belvoir	430.7	50.5%
Shenandoahs Pride Dairy	VAR051100	Fairfax County	7.3	50.5%
Federal Express Corporation	VAR051109	Fairfax County	3.9	50.5%
G and L Metals	VAR051134	Fairfax County	1	50.5%
Rolling Frito Lay Sales LP	VAR051565	Fairfax County	4.1	50.5%
National Asphalt Paving Corporation	VAR051719	Fairfax City	2.7	50.5%
Jermantown Maintenance Facility	VAR051770	Fairfax City	10.8	50.5%
Newington Maintenance Facility	VAR051771	Fairfax County	25	50.5%
DVS - Alban Maintenance Facility	VAR051772	Fairfax County	4.7	50.5%
HD Supply - White Cap	VAR051795	Fairfax County	0.2	50.5%
United Parcel Service - Newington	VAR051863	Fairfax County	13.7	50.5%
Concrete Facilities Stormwater General Permits				
Newington Concrete Corporation	VAG110046	Fairfax County	1.2	50.5%
Virginia Concrete Company	VAG110069	Fairfax County	4.5	50.5%
		Total	**674.8**	**50.5%**

All the acreages for all the permits listed in **Table 6-5** were assumed to be within the industrial land use category except for Fort Belvoir Davison Army Airfield (VAR051080) and the Fairfax Terminal Complex (VA0001872). The permit for Fort Belvoir Building 1442 covers 430.7 acres, however the land use information provided by Fairfax County indicates there are only 221.4 acres of industrial land use within the Fort Belvoir MS4 area. Accordingly, for purposes of this TMDL, it was assumed that half the permitted acreage (215.35 acres) is within the industrial land use category and the other half within the open space category. An assessment of the facility using GIS imagery confirms this is an appropriate assumption. Similarly, in the City of Fairfax MS4 area there are a total 4 permits (VA0001872, VA0002283, VAR051719 and VAR051770) covering 124.5 acres; however the land use data provided by Fairfax County indicates there are only 123.1 acres in the industrial land use category. Accordingly, for purposes of this TMDL, it was assumed that 1.4 of the 106.4 acres covered under the Fairfax Terminal Complex (VA0001872) permit are within the open space land use category.

WLAs were developed for each facility listed in **Table 6-5** using the information presented in **Table 6-4**. These WLAs were subtracted from the corresponding MS4 allocation in which the stormwater permit is located. **Table 6-6** presents the aggregate WLAs for the VPDES individual, general industrial, and general concrete stormwater permits. More in-depth information, including the existing and post-TMDL conditions for each permittee, is presented in **Appendix B**.

Table 6-6: WLAs for Industrial Stormwater Permits

Stormwater Permit Type	Acres	Existing Conditions (ft^3/acre-day)	Allocation (ft^3/acre-day)	Percent Reduction of One-Year, 24-Hour flow
Individual Industrial	143.4	11.48	5.68	50.5%
General Industrial	525.7	26.87	13.31	50.5%
General Concrete	5.7	0.456	0.226	50.5%
Total	**674.8**	**38.80**	**19.22**	**50.5%**

6.3.2 Aggregate WLAs for MS4 Permits and Construction Stormwater Permits

Table 6-7 provides aggregate WLAs that include discharges subject to MS4 permits and discharges subject to construction stormwater permits. As explained in Section 2.4, the current data for construction stormwater permits indicates that 1,077 acres (approximately 3.5% of the total acreage in the watershed) were under construction in the Accotink Creek watershed in October, 2010. Because the current construction activity is a temporary snapshot in time, and because the level of future construction activity at any given time in this watershed is difficult to predict given the information available, EPA did not estimate a separate WLA for construction, but rather aggregated any potential construction WLA with the MS4 allocations. That said, all construction activities within the watershed must meet the requirements provided within applicable construction permits, including sediment and stormwater controls.

Additionally, the aggregate WLAs provide flexibility for permittees and the permitting authority to include flow reductions for construction permits as a possible stormwater management practice to meet the overall reductions required by the TMDL. EPA believes that newly developed and re-developed sites provide the best opportunity to meet the flow reduction requirements of this TMDL.

There are 6 permitted MS4s in the Accotink Creek Watershed. **Figure 2-5** depicts the geographic coverage of each MS4 in Accotink Creek except the VDOT MS4 which is composed of the transportation network incorporated within each MS4. Most of the public roads (interstate, primary, and secondary) in the Accotink Creek watershed are maintained by VDOT.

The discharge reductions presented in **Table 6-4** are based on the assumption that stormwater runoff from 90% of all land uses in the watershed, including the Transportation category, drain to regulated storm sewer systems. Therefore, it is an assumption of this TMDL that all the transportation acres included in the WLA (4,190.4 acres) fall under the jurisdiction of the VDOT MS4. **Table 6-7** provides a summary of the aggregated allocations for MS4s and construction stormwater permits in the Accotink Creek watershed.

Table 6-7: Aggregated MS4 and Construction Stormwater Wasteload Allocation

MS4	Acres	Reduction to the one-year, 24-hour Flow*
Fairfax County	17,998.3	47.2%
City of Fairfax	2,726.7	49.6%
Town of Vienna	829.35	49.3%
Fort Belvoir	870.25	25.9%
VDOT	4109.4	50.5%
NOVA Community College	67.5	50.3%
Total	**26,601.5**	**48.3%**

* The varying percent reductions in this table reflects differences in land use distribution within each MS4; MS4s with less open space will have a higher reduction than the overall 48.4% reduction needed to meet the end point, whereas MS4s with more open space will have a lower reduction than the overall 48.4% reduction.

It is important to note that the aggregated WLAs in **Table 6-7** are expressed in terms of stormwater flow rate reduction, with the ultimate goal of reducing the impacts of sediment transport on aquatic life. However, as noted in section 8.2 below, the assumptions and requirements of these wasteload allocations do not preclude the MS4 permitting authority from allowing for non-flow BMPs/actions to be used for implementation of these WLAs by MS4s, in order to encourage a comprehensive approach to reducing sediment within Accotink Creek and addressing the benthic impairments. In this case, the non-flow BMPs/actions should be accompanied by a quantitative analysis of their effect on sediment transport and relate that effect to a corresponding flow reduction.

6.4 Overall TMDL Allocations

The final allocations for each source within the watershed are summarized in **Table 6-8.** Overall, the magnitude of the one-year, 24-hour stormwater flow rate in the Accotink Creek watershed must be reduced by 48.4% in order to meet the established TMDL endpoint. The stormwater TMDLs for Accotink Creek are summarized in **Table 6-9** and **Table 6-10.**

Table 6-8: Summary of Existing and Allocated Stormwater Flows

Source	Allocation Category	Acres	Existing Conditions (ft^3/acre-day)	Allocation (ft^3/acre-day)	Percent Reduction
Point Sources (WLA)	MS4 and Construction Stormwater Permits	26,601.5	1,150.7	594.4	48.30%
	Industrial Stormwater Permits	674.8	38.8	19.2	50.50%
	WLA Totals	**27,276.3**	**1,189.5**	**613.6**	**48.40%**
	Nonpoint Sources (LA)	**3,030.7**	**132.2**	**68.2**	**48.40%**
	TMDL Total	**30,307**	**1,321.7**	**681.8**	**48.40%**

Table 6-9: Stormwater TMDL for Accotink Creek (ft^3/acre-day)

TMDL	Load Allocation	Wasteload Allocation	Margin of Safety
681.8	**68.2**	**613.6**	**Implicit**

Table 6-10: Stormwater TMDL for Accotink Creek (Percent Reduction of the One-Year, 24-Hour flow)

TMDL	Load Allocation	Wasteload Allocation	Margin of Safety
48.4%	**48.4%**	**48.4%**	**Implicit**

The Accotink Creek Stormwater TMDL implicitly expresses the allocations in daily terms. All the allocations presented in this report are for a 24-hour period since the basis for developing the TMDL was the flow rate target that occurs once every year during a 24-hour period.

6.5 Margin of Safety

The CWA requires that a TMDL include a MOS to account for any lack of knowledge concerning the relationship between the TMDL allocations and water quality. The MOS may be implicit (i.e., built into the modeling process by using conservative modeling assumptions) or explicit (i.e., a percentage of the WLA, LA, or TMDL).

An implicit MOS has been incorporated into this TMDL by reducing uncertainty in the allocations and by incorporating a number of conservative assumptions in the development of the TMDL target and allocations. For example, by comparing Accotink Creek with multiple attainment streams in the Commonwealth of Virginia, uncertainty in the TMDL allocations was reduced. To limit the uncertainty associated with the use of any single reference watershed, flow data from Buffalo and Catoctin Creeks were used to develop a composite FDC for TMDL target-setting purposes. This composite FDC represents the average values of the flow data collected from two attainment streams, thus creating a more robust attainment FDC that accounts for a broader range of conditions, including eco-region, soils, slope, and land-use.

In addition, the TMDL target flow rate of 681.8 ft^3/acre-day represents a conservative value. According to the attainment stream approach, by definition, the flows for the attainment streams represent flows under which the Aquatic Life criteria are currently being met. It is reasonable to assume that the maximum flows in the attainment streams would allow Accotink Creek to comply with Virginia's water quality standards. However, EPA based the TMDL target on a composite FDC which was calculated based on the average value (as opposed to the maximum value) of the ranked unit-area flow rates in Buffalo Creek and Catoctin Creek. If the composite FDC had been developed using the maximum unit-area flow rates, the corresponding one-year, 24-hour target flow rate would have been higher than 681.8 ft^3/acre-day, and would have resulted in the establishment of a less conservative TMDL target. Thus, EPA's conservative use of the average unit-area flow rate instead of the maximum unit-area flow rate to establish the composite FDC and TMDL target provided an implicit MOS to the TMDL.

Finally, the use of attainment streams that are above the "threshold" of attainment represents another conservative assumption in the TMDL allocations. The VSCI scores for Buffalo Creek and Catoctin Creek consistently exceed the attainment threshold score of 60.0. Table 5-5 of the TMDL report provides a complete list of VSCI scores for both Buffalo Creek and Catoctin Creek. The VCSI scores in Buffalo Creek range from 61.0 (Spring 2006) to 81.7 (Fall 2006), with an average score of 71.7, while the VSCI scores in Catoctin Creek range from 54.99 (Spring 2003) to 75.5 (Fall 1997), with an average score of 69.2. DEQ considers streams with a VSCI score between 60-72 to be in "good" condition. DEQ considers streams with a VSCI equal to or greater than 73 to be in "excellent" condition (VADEQ 2006). The average VSCI scores for both Buffalo Creek (71.7) and Catoctin Creek (69.2) fall within the "good" range, not the "excellent" range. As a result, the flow data from the attainment streams that was used to develop the composite FDC represent flows that are better than needed for attainment (without being overly protective), thus adding an additional implicit MOS to the TMDL.

6.6 Future Growth

EPA believes that new development and redevelopment provide the best opportunity to reduce stormwater flows. To meet the overall TMDL goal of a 48.4 percent reduction in the 1-year, 24-hour flow rate across the watershed, future permits authorizing new or expanded stormwater discharges within the Accotink Creek watershed must be consistent with the requirements and assumptions used to develop the WLAs in this TMDL.

6.7 Consideration of Seasonal Variability

The CWA requires that a TMDL be established with consideration of seasonal variations. The technical approach for this TMDL is based on the use of FDCs for defining hydrologic targets. The FDCs incorporate the complete spectrum of flow conditions, from very low to very high, that occur in the stream system over a period of 20 years. Therefore, the FDCs developed for this TMDL implicitly incorporate all seasonal flow variability.

6.8 Consideration of Critical Conditions

EPA regulations at 40 CFR 130.7(c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that designated uses are protected throughout the year, including times when waterbodies are most vulnerable. For the biological impairments in the Accotink Creek watershed, critical conditions occur during high-flow periods, when excessive stormwater runoff generates increased sediment loads from in-stream sources (e.g., bank erosion), causing habitat degradation for aquatic life (e.g., siltation, scour, over-widening of stream channel) and washout of biota. Critical conditions were inherently considered in the Accotink Creek stormwater TMDL by using a FDC approach with a one-year, 24-hour flow target. FDCs incorporate the full range of flow conditions from very low to very high, including the critical conditions that occur in the stream system over a long period of time (a 20-year period for the Accotink Creek TMDL). Additionally, use of the one-year, 24-hour flow as a TMDL endpoint, which is close to the upper end of the high-flow portion of the FDC, provides additional assurance that the critical conditions are fully taken into account. Selecting a TMDL target close to the upper end of the FDC ensures that the implementation measures chosen to meet the target will also reduce the impact of the full range of storm events that drive the shape of the entire FDC.

7.0 Public Participation

The development of the Accotink Creek stormwater TMDL would not have been possible without public participation. Five technical advisory committee (TAC) meetings and two public meetings were held to discuss the impairments in Accotink Creek, present the results of the stressor identification analysis, as well as discuss the most efficient technical approach to develop the TMDL. The following is a summary of the key meetings held for the Accotink Creek TMDL.

Preliminary TAC Meetings: Two Preliminary TAC meetings were held in April and September 2008 to present and review the steps and the data used in the development of the stormwater TMDL for the Accotink Creek listed segments. These meetings were hosted by DEQ and USEPA and were held at the Northern Virginia Regional Commission offices and the Fairfax County Government Center in Fairfax, Virginia.

TAC Meeting No. 1: The first TAC meeting was held on December 15, 2008 at the Fairfax County Government Center in Fairfax, Virginia to discuss the preliminary benthic stressors identified for Accotink Creek.

TAC Meeting No. 2: The second TAC meeting was held on August 18, 2009 at the Fairfax County Government Center in Fairfax, Virginia to present the potential technical approaches that could be used to develop the Accotink Creek stormwater TMDL. A 30-day comment period was held from August 18 through September 18, 2009 on the information presented at this meeting. A list of the comments that were submitted during this period, as well as EPA's responses, are provided in EPA's *TMDL Development for Benthic Impairments in the Accotink Creek Watershed: Response to Comments Document.*

Public Meeting No. 1: The first public meeting was held on September 29, 2009 at Fairfax County Government Center in Fairfax to present the process for TMDL development, the Accotink Creek benthic impaired segments, data that caused the segments to be on the 303(d) list, data and information needed for TMDL development, and preliminary findings regarding the potential stressors and technical approaches.

Copies of the presentation were available for public distribution. This meeting was publicly noticed in the *Virginia Register*. A 30-day comment period was held from September 29 through October 29, 2009 on the information presented at this meeting. A list of the comments that were submitted during this period, as well as EPA's responses, are provided in EPA's *TMDL Development for Benthic Impairments in the Accotink Creek Watershed: Response to Comments Document.*

TAC Meeting No. 3: The third TAC meeting was held on January 19, 2010 at the Fairfax County Government Center in Fairfax, Virginia to discuss EPA's draft TMDL for the Accotink Creek watershed. A 30-day comment period was held from January 19 through February 26, 2010 on the information presented at this meeting. A list of the comments that were submitted during this period, as well as EPA's responses, are provided in EPA's *TMDL Development for Benthic Impairments in the Accotink Creek Watershed: Response to Comments Document.*

Final Public Meeting: A final public meeting was held on July 26, 2010 to discuss EPA's draft TMDL for the Accotink Creek watershed. This meeting was publicly noticed in the *Virginia Register*. A 45-day comment period was held from July 5 through August 20, 2010 on the information presented at this meeting. A list of the comments that were submitted during this period, as well as EPA's responses, are provided in EPA's *TMDL Development for Benthic Impairments in the Accotink Creek Watershed: Response to Comments Document.*

8.0 Reasonable Assurance

When a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur, the TMDL must provide reasonable assurance that nonpoint source control measures will achieve the expected load reductions. As explained in Section 6, the stormwater TMDL developed for Accotink Creek requires reductions from both point and nonpoint sources. Accordingly, the TMDL must provide reasonable assurance that these reductions can be achieved.

8.1 Load Allocations

The implementation of pollutant reductions from nonpoint sources relies heavily on incentive-based programs; however Virginia has a number of funding programs in place to ensure that the LAs assigned to nonpoint sources in the Accotink Creek stormwater TMDL can be achieved. Some of the potential sources of funding for LA implementation include the USEPA's Section 319 funds, the Virginia State Revolving Loan Program (also available for permitted activities), the Virginia Water Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits, and landowner contributions. With additional appropriations for the Virginia Water Quality Improvement Fund (WQIF) during the Commonwealth's last two legislative sessions, the Fund has become another potential monetary resource that can be used to address urban and residential water quality problems such as those found in Accotink Creek. Information on WQIF projects and allocations can be found at: http://www.deq.virginia.gov/bay/wqif.html and http://www.dcr.virginia.gov/soil_&_water/wqia.shtml.

With various funding mechanisms at their disposal, the municipalities within the Accotink Creek watershed have initiated several programs and projects related to water quality improvement and watershed management. Fairfax City, for example, has completed a series of stream restoration projects aimed at restoring water quality in Accotink Creek. Since 1994, the city has implemented bioengineering restoration measures in over four miles of tributaries to Accotink Creek. As part of these projects, channel grading and native vegetation was used to reduce stream bank erosion, and rock structures were installed to deflect erosive stream velocities.

Similarly, The Fairfax County Park Authority initiated a project in the summer of 2001 to dredge approximately 200,000 cubic yard of sediment from Lake Accotink. During the study phase for the project, it was identified that several areas upstream of the lake needed stream stabilization and restoration measures to help control the generation of sediment due to stream channel erosion. This is viewed to be the long-term solution to the sedimentation problem being experienced within the lake.

Along with these projects, the Stormwater Planning Division of the Fairfax County Department of Public Works and Environmental Services (DPWES) is developing a watershed management plan for Accotink Creek that will also address water quality and quantity issues. The plan will provide an assessment of management needs and will prioritize solutions within the watershed. The overall goal of the project is to provide a consistent basis for the evaluation and implementation of solutions for protecting and restoring receiving water systems and other natural resources within the Accotink Creek watershed. Public participation will be a critical component of the watershed management plan, and watershed groups have been instrumental in achieving water quality improvements. Groups like The Friends of Accotink Creek have cleaned up adopted stretches of Accotink Creek, provided invasive species management, participated in stream restoration projects, and conducted biological monitoring within the stream.

8.2 Wasteload Allocations

The issuance of a National Pollutant Discharge Elimination System (NPDES) permit provides the reasonable assurance that the WLAs assigned to point sources in the Accotink Creek stormwater TMDL will be achieved. This is because 40 CFR 122.44(d)(1)(vii)(B) requires that effluent limits in permits be consistent with "the assumptions and requirements of any available wasteload allocation" in an EPA-approved TMDL. Furthermore, EPA has the authority to object to the issuance of an NPDES permit that is inconsistent with WLAs established for that point source, which will have to be achieved by traditional point sources, as well as more diffuse sources such as permitted MS4 systems.

In Virginia, implementation of the WLA component of this TMDL will be achieved through the VPDES permit program, the Virginia Stormwater Management Act, Virginia Code § 10.1-600 et seq., and the Virginia Stormwater Management Program (VSMP) Permit Regulations 4 VAC 50-60-10 et seq. DEQ and DCR coordinate separate Commonwealth programs that regulate the management of pollutants carried by stormwater runoff. Among other regulatory authorities, DEQ regulates stormwater discharges associated with "industrial activities", while DCR regulates stormwater discharges from construction sites and MS4s. This dual permitting authority provides Virginia with powerful tools for requiring the implementation of stormwater treatment and control practices necessary to meet the WLA reduction targets in this TMDL.

While implementation generally is beyond the scope of this TMDL, in light of significant public interest, EPA provides the following clarification of the assumptions and requirements of this TMDL. EPA anticipates that implementation of the Accotink Creek stormwater TMDL WLA will be achieved over the course of multiple permit cycles using an iterative, adaptive approach to stormwater management. EPA's November 22, 2002 guidance document titled "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on those WLAs," states:

> The policy outlined in this memorandum affirms the appropriateness of an iterative, adaptive management BMP approach, whereby permits include effluent limits (e.g., a combination of structural and non-structural BMPs) that address storm water discharges, implement mechanisms to evaluate the performance of such controls, and make adjustments (i.e., more stringent controls or specific BMPs) as necessary to protect water quality. This approach is further supported by the recent report from the National Research Council (NRC), Assessing the TMDL Approach to Water Quality Management (National Academy Press, 2001). The NRC report recommends an approach that includes "adaptive implementation," i.e., "a cyclical process in which TMDL plans are periodically assessed for their achievement of water quality standards" . . . and adjustments made as necessary. NRC Report at ES-5.

The iterative approach also is consistent with the clarifying guidance recently issued by EPA on November 12, 2010, EPA. The November 12, 2010 Memorandum states:

> The permitting authority's decision as to how to express the WQBEL(s), either as numeric effluent limitations or BMPs, including BMPs accompanied by numeric benchmarks, should be based on an analysis of the specific facts and circumstances surrounding the permit and/or the underlying WLA, including the nature of the stormwater discharge, available data, modeling results or other relevant information. As discussed in the 2002 memorandum, the permit's administrative record needs to provide an adequate demonstration that, where a BMP-based approach to permit limitations is selected, the BMPs required by the permit will be sufficient to implement applicable WLAs. Improved knowledge of BMP effectiveness gained since 2002 should be reflected in the demonstration and supporting rationale that implementation of the BMPs will attain water quality standards and WLAs.
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> * * * *
>
> Lastly, NPDES permits must specify monitoring requirements necessary to determine compliance with effluent limitations. See CWA section 402(a)(2); 40 C.F.R. § 122.44(i). Where WQBELs are expressed as BMPs, the permit must require adequate monitoring to determine if the BMPs are performing as necessary. When developing monitoring requirements, the NPDES authority should consider the variable nature of stormwater as well [as] the availability of reliable and applicable field data describing the treatment efficiencies of the BMPs required and supporting modeling analysis.

EPA expects that the NPDES permitting authority will review the information provided by the TMDL and determine whether the effluent limit is appropriately expressed using an iterative BMP approach or a numeric limit.

The above noted clarification memorandum affirms the appropriateness of an iterative, adaptive management BMP approach, whereby permits include effluent limits (a combination of structural and non-structural BMPs) that address stormwater discharges, implement mechanisms to evaluate the performance of such controls, and make adjustments as necessary to protect water quality in a documented and quantifiable manner.

As explained in Section 6.3.2, it is important to note that the WLAs assigned to point sources in this TMDL are expressed in terms of stormwater flow rate reduction, with the ultimate goal of reducing the impacts of sediment transport on aquatic life. However, the assumptions and requirements of this TMDL do not preclude the permitting authority from allowing use of non-flow BMPs/actions for implementation of these WLAs in order to encourage a comprehensive approach to reducing sediment within Accotink Creek and addressing the benthic impairments. In this case, the non-flow BMPs/actions should be accompanied by a quantitative analysis of their effect on sediment transport and relate that effect to a corresponding flow reduction. Thus, EPA anticipates the use of a coordinated, comprehensive approach to TMDL implementation that relies upon an appropriate mix of available implementation "tools". This comprehensive implementation approach could include BMPs that directly restore/improve aquatic habitat (such as streambank restoration and reconnection of the floodplain to the stream), as well as BMPs that directly address the existing hydrologic alteration (such as green roofs, pervious pavements, rain gardens, and other low impact development/green infrastructure techniques). As part of this comprehensive implementation strategy, EPA anticipates the use of an iterative, adaptive management approach to assess progress, with appropriate monitoring, so that any necessary corrections can be made as implementation proceeds over time.

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APPENDIX A

Land Use Distributions for the MS4s in the Accotink Creek Watershed

The land use distributions for each MS4 permittee are presented below. These land use distributions are the results of the disaggregation of the initial land use distributions and do not include the overall 10% assigned to the load allocation (LA), the specific acreage for the VDOT MS4, and the acreage for each specific stormwater permittee (individual, general permit, concrete) within each jurisdiction.

Table A-1: Fairfax County MS4 Landuse

MS4	Landuse Description	Acreage
Fairfax County (VA0088587)	Estate Residential	287.1
	Golf Course	132.3
	High Density Residential	2,334.6
	High Intensity Commercial	434.7
	Industrial	1,270.0
	Institutional	919.8
	Low Density Residential	2524.5
	Low Intensity Commercial	478.8
	Medium Density Residential	5,407.7
	Open Space	4,209.3
	Transportation	0.0
	Total	**17,998.3**

Table A-2: City of Fairfax MS4 Landuse

MS4	Landuse Description	Acreage
City of Fairfax (VAR040064)	Estate Residential	50.4
	Golf Course	182.7
	High Density Residential	317.7
	High Intensity Commercial	233.1
	Industrial	5.1
	Institutional	186.3
	Low Density Residential	337.5
	Low Intensity Commercial	256.5
	Medium Density Residential	956.7
	Open Space	200.7
	Transportation	0.0
	Total	**2,726.7**

Table A-3: Fort Belvoir Military Reservation MS4 Landuse		
MS4	**Landuse Description**	**Acreage**
Fort Belvoir Military Reservation (VAR040093)	Estate Residential	0.45
	Golf Course	302.4
	High Density Residential	2.7
	Industrial	17.75
	Institutional	93.6
	Open Space	453.35
	Transportation	0
	Total	**870.3**

Table A-4: Town of Vienna MS4 Landuse		
MS4	**Landuse Description**	**Acreage**
Town of Vienna (VAR040066)	Estate Residential	6.8
	High Density Residential	47.7
	High Intensity Commercial	13.5
	Industrial	1.8
	Institutional	54.9
	Low Density Residential	95.4
	Low Intensity Commercial	19.8
	Medium Density Residential	525.6
	Open Space	63.9
	Transportation	0
	Total	**829.4**

Table A-5: NOVA Community College MS4 Landuse		
MS4	**Landuse Description**	**Acreage**
NOVA CC (VAR040095)	Institutional	63.0
	Low Intensity Commercial	3.6
	Open Space	0.9
	Transportation	0
	Total	**67.5**

APPENDIX B

Industrial Stormwater Permits in the Accotink Creek Watershed

Table B-1: Industrial Stormwater Discharge Permit Allocations

Facility Name	Permit Number	Drainage Area (acres)	Existing Conditions (ft^3/acre-day)	Allocation (ft^3/acre-day)	Percent Reduction
Fairfax Terminal Complex	VA0001872	106.4	8.51	4.22	50.5%
Kinder Morgan Southeast Terminals	VA0001945	17.9	1.43	0.71	50.5%
Motiva Enterprises LLC	VA0001988	10.9	0.87	0.43	50.5%
Motiva Enterprises LLC - Fairfax	VA0002283	4.6	0.37	0.18	50.5%
Quarles Petroleum - Newington	VA0057380	3.6	0.29	0.14	50.5%
Canada Dry - Springfield	VAR050988	4	0.32	0.16	50.5%
SICPA Securink Corporation	VAR051042	7.5	0.60	0.30	50.5%
Connector Bus Yard	VAR051047	6.3	0.50	0.25	50.5%
United Parcel Service	VAR051053	2	0.16	0.08	50.5%
US Postal Service - Merrifield	VAR051066	1.8	0.14	0.07	50.5%
Fort Belvoir Davison Army Airfield	VAR051080	430.7	19.27	9.54	50.5%
Shenandoahs Pride Dairy	VAR051100	7.3	0.58	0.29	50.5%
Federal Express Corporation	VAR051109	3.9	0.31	0.15	50.5%
G and L Metals	VAR051134	1	0.08	0.04	50.5%
Rolling Frito Lay Sales LP	VAR051565	4.1	0.33	0.16	50.5%
National Asphalt Paving Corporation	VAR051719	2.7	0.22	0.11	50.5%
Jermantown Maintenance Facility	VAR051770	10.8	0.86	0.43	50.5%
Newington Maintenance Facility	VAR051771	25	2.00	0.99	50.5%
DVS - Alban Maintenance Facility	VAR051772	4.7	0.38	0.19	50.5%
HD Supply - White Cap	VAR051795	0.2	0.02	0.01	50.5%
United Parcel Service - Newington	VAR051863	13.7	1.10	0.54	50.5%
Newington Concrete Corporation	VAG110046	1.2	0.10	0.05	50.5%
Virginia Concrete Company	VAG110069	4.5	0.36	0.18	50.5%
	Total	**674.8**	**38.80**	**19.22**	**50.5%**

MS4 Permits in the Accotink Creek Watershed

Table B-2: MS4 Permit Allocations

MS4 Permit	Acres	Existing Conditions (ft^3/acre-day)	Allocation (ft^3/acre-day)	Percent Reduction
Fairfax County	17,998.3	611.6	322.95	47.20%
City of Fairfax	2,726.7	114.85	57.84	49.6%
Town of Vienna	829.35	25.99	13.18	49.3%
Fort Belvoir	870.25	12.96	9.61	25.9%
VDOT	4109.4	383.12	189.24	50.5%
NOVA Community College	67.5	3.20	1.59	50.3%
Total	**26,601.5**	**1,150.7**	**594.4**	**48.3%**

APPENDIX C

Relationship between Impervious Cover, Stormwater Runoff and Sediment Loads in the Accotink Creek Watershed

Introduction

As described in depth within the TMDL report, two segments of Accotink Creek in Fairfax County, Virginia are listed on Virginia's Section 303(d) list for not meeting the aquatic life use due to poor health in the benthic biological community. A stressor analysis identified sedimentation caused by excessive urban stormwater runoff as the most probable source of the impairments. Common ways to address biological impairments through TMDLs often focus on sediment.

In the case of the Accotink Creek benthic impairments, a TMDL was developed using "other appropriate measures" (or surrogates) as provided under EPA regulations (40 CFR 130.2(i)) to reflect detailed analysis of habitat degradation and the role of sediment. A TMDL can be expressed in terms of stormwater flow rate or flow reduction where "flow" is used as a surrogate for a variety of pollutants (in this case, sediment) associated with stormwater discharges. Section 303(d)(1)(C) of the CWA requires that "Each State shall establish for waters identified [on its Section 303(d) list] … the total maximum daily load, for those pollutants which the Administrator identifies under section 1314(a)(2) of this title as suitable for such calculation." 33 U.S.C. 1313(d)(1)(C). The rate of flowing water may affect hydrologic and geomorphologic changes that, in turn, affect aquatic life. It is important to note that by itself, flow rate is not a "pollutant" as defined under Section 502(6) of the CWA. 33U.S.C. 1362(6). Nevertheless, numerous studies have recognized that there are pollutants associated with stormwater that can affect aquatic life. In addition, excess stormwater flow may cause scour and resuspension of sediment (a pollutant) in receiving waters.

From a technical perspective, it is extremely difficult to separate the effects on aquatic life caused by changes in the hydrology or geomorphology of the water from those caused by the pollutants entrained in the stormwater (including re-suspended sediment caused by stormwater flow). Accordingly, EPA believes it is appropriate in a TMDL analysis for stormwater to serve as a surrogate for the presence of these pollutants. By expressing the TMDL in terms of stormwater flow rate reductions, the TMDL will address the aquatic life impacts caused by the pollutants in stormwater. As a secondary effect, the TMDL will also address both the hydrologic/geomorphologic impacts of stormwater. In the Accotink Creek TMDL, hydrologic targets are used as a surrogate measure to address the biological impairments. This Appendix further explains and relates the biological impairments in Accotink Creek and its relationship with stormwater runoff, sediment loads and impervious cover within the Accotink Creek Watershed.

The Relationship between Sediment and Flow

The primary pollutant of concern in Accotink Creek is sediment. However, as the TMDL document explains, the TMDL uses the surrogate of stormwater runoff flow rate to address the needed reductions in sediment. Use of this surrogate is appropriate because the amount of pollutant load discharged is a function of the amount of stormwater runoff generated from a watershed for a given set of conditions. This relationship is especially strong for sediment.

Biological communities are subjected to many stressors associated with sediment and stormwater runoff. Excessive sedimentation can impair benthic communities through loss of habitat, and can result in low scores for habitat metrics such as bank stability, embeddedness, riparian vegetation, and sediment deposition. As documented in the TMDL report, the Accotink Creek watershed is characterized by a very flashy hydrology associated with larger, briefer, and more frequent flows resulting in large rates of urban runoff and increased flow rates. As runoff enters Accotink Creek during precipitation events, increased sediment loads are generated from in-stream sources including bank erosion and gully erosion (**Figure C-1**). Bank erosion is driven by channel stability, discharge rates and stream velocities. The bank erosion delivers sediment loads in the Accotink Creek that impairs the macroinvertebrates by filling in the pores of gravel and cobble substrate, eliminating macroinvertebrate habitat. In addition the stormwater degrades the habitat causing scour, erosion, over-widening of the stream, and siltation downstream as fine sediments are transported out of the upstream reach of Accotink Creek and are deposited downstream close to the tidal boundary (**Figure C-2**) where they bury/smother benthic macroinvertebrates. As a result of these impacts, habitat assessment scores in Accotink Creek indicated marginal to poor scores for epifaunal substrate, embeddedness, sediment deposition, and bank stability. Consequently, the habitat assessment scores indicated that sedimentation and stormwater runoff were the most probable stressors to the benthic community in the Accotink Creek watershed.

Figure C-1: Accotink Creek Streambank Erosion (From Fairfax County Brochure – 09/ 2008)

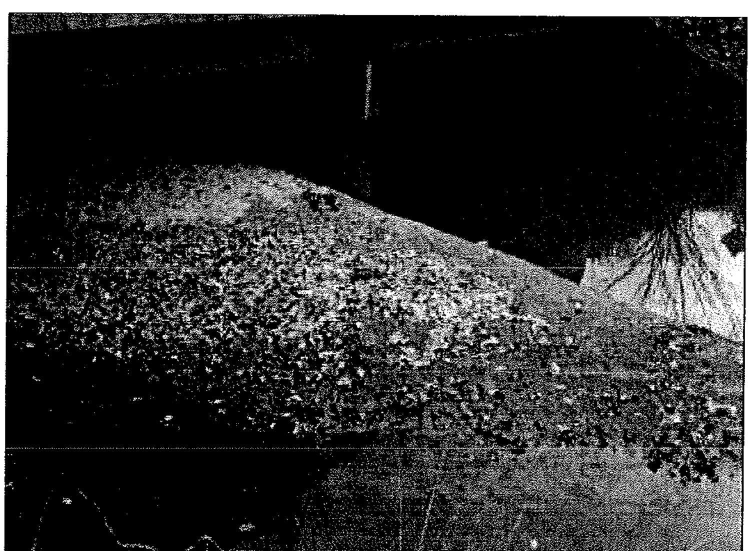

Figure C-2: Fine Sand Deposit Located Under the Route 1 Bridge over Accotink Creek, near the Tidal/Non-Tidal Boundary

To demonstrate the direct relationship between stormwater flow and sediment loads, in Accotink Creek, stream flow and sediment data collected concurrently at USGS Station 01654000 and DEQ water quality station AACO014.57 were used to develop a sediment rating curve for Accotink Creek (**Figure C-3**). The sediment rating curve characterizes sediment loads at different flow regimes. A total of 84 observations of sediment and flow collected concurrently and spanning the period of 1993 to 2007 were used to develop the rating curve.

TSS data were collected in Accotink Creek during a wide range of flow conditions, including high and low-flow conditions. The resulting rating curve shown in **Figure C-4** demonstrates that there is a strong relationship between stream flow and stream sediment loads in Accotink Creek. **Figure C-5** depicts the streamflow data between 1988 and 2007 along with the dates where the sediment data were also collected. **Figure C-5** demonstrates that the TSS data was collected over a wide range of flow conditions and that as flow increased, TSS increased. Similarly, as flow decreased, TSS decreased.

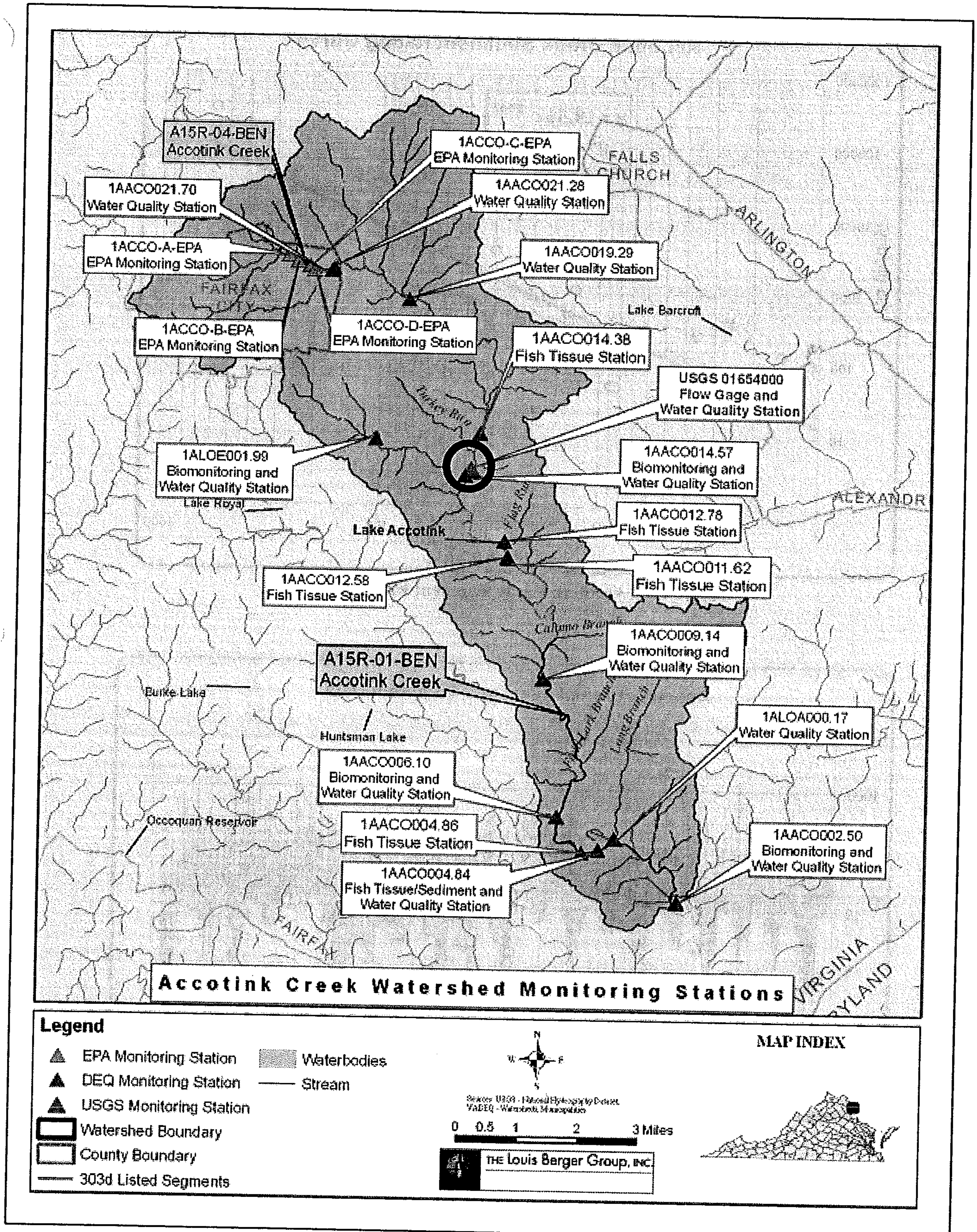

Figure C-3: Monitoring Locations in the Accotink Creek Watershed

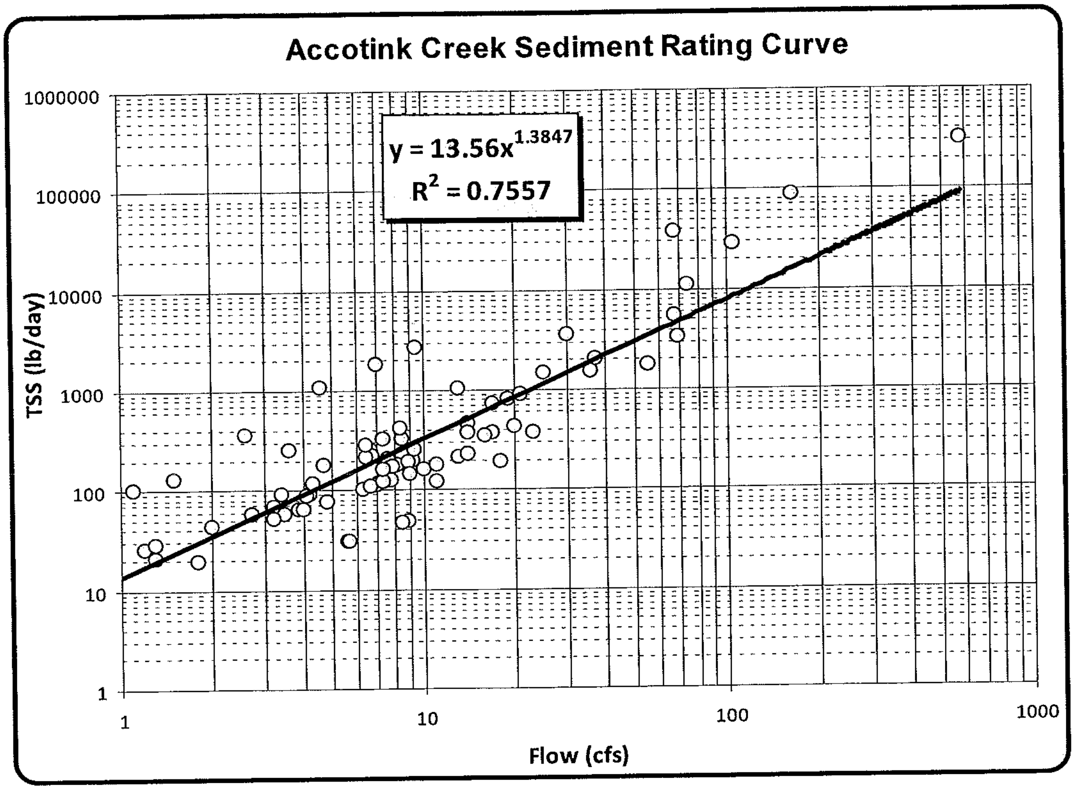

Figure C-4: Accotink Creek Sediment Rating Curve

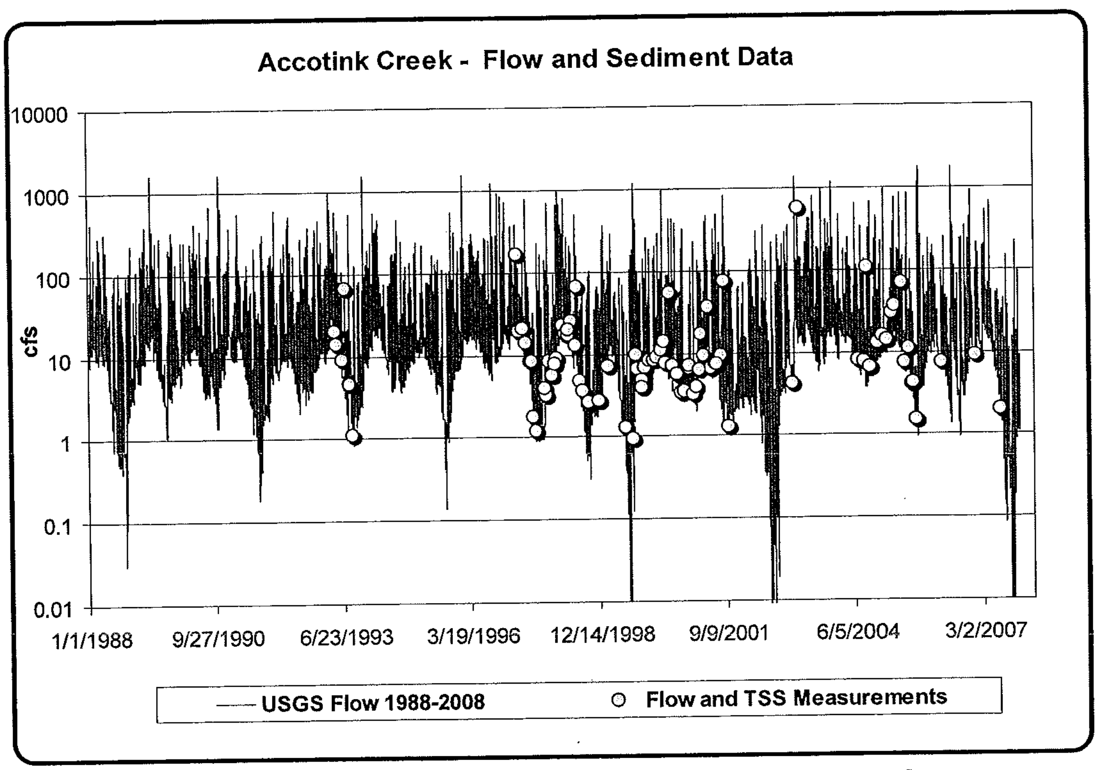

Figure C-5: Accotink Creek Sediment and Flow Collection Periods

A sediment load duration curve for the Accotink Creek is developed to characterize the sediment loads at different flow regimes and to display the relationship between stream flow and sediment loading capacity. The sediment load duration curve is developed using the flow duration curve (FDC) for Accotink Creek and applying to each flow value of the FDC the sediment rating curve equation shown in **Figure C-4**. The sediment load duration curve for the Accotink Creek is depicted in **Figure C-6** and indicates that sediment loads increased significantly in the high-flow zone (i.e. the upper ten percent of all daily average flows). These figures (rating curve and load duration curve) all document the significant relationship between stream flow and sediment loads in Accotink Creek, and provide the basis for using flow as a surrogate for sediment in a TMDL. Efforts to reduce stormwater flow will decrease sediment loads, particularly the instream sediment loads, which in turn will improve habitat for the macroinvertebrate communities within the stream.

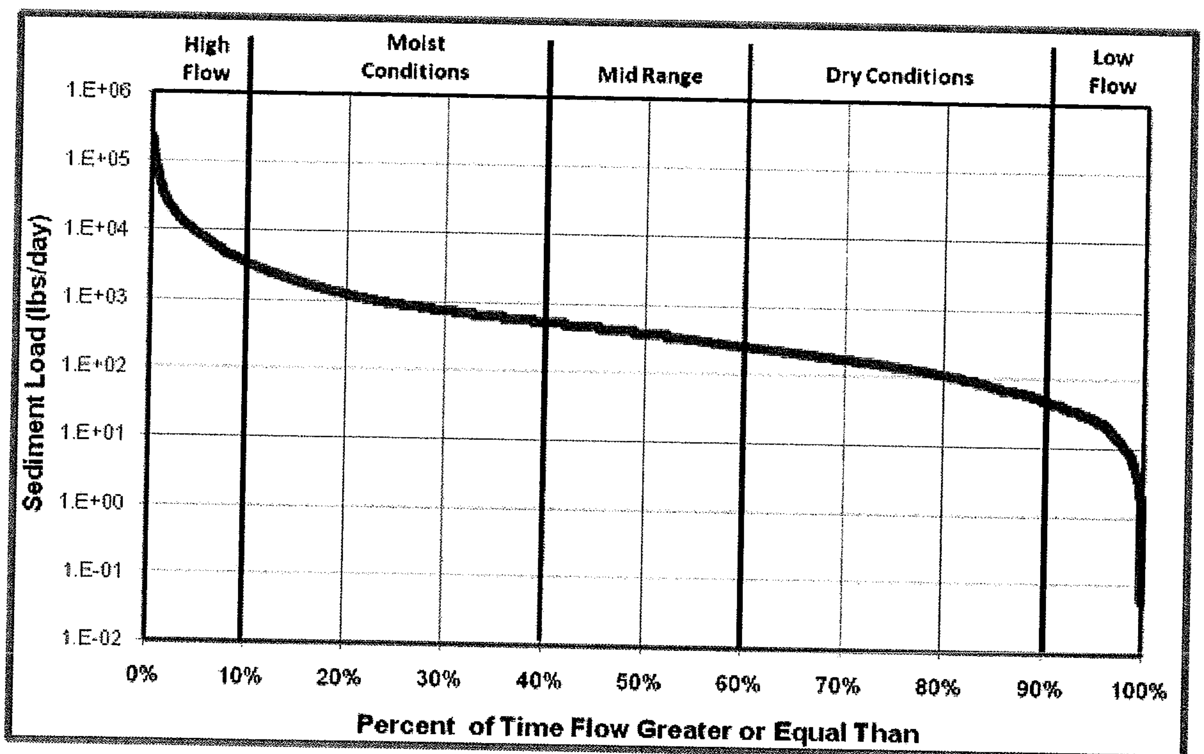

Figure C-6: Accotink Creek Sediment Load Duration Curve

The Relationship between Stormwater Flows and Impervious Cover (IC)

Over the last decade, there has emerged a widespread recognition and a strong scientific consensus that the natural flow regime plays a critical role in sustaining the ecosystem integrity of rivers and streams. A review of the literature indicates there is a relationship between increases in impervious cover (IC) and the resulting hydrologic alteration and stream ecosystem impairment (Arnold and Gibbons, 1996, CWP, 2003, 2005, Klein, 1979, Miltner et al. 2004) . The effect of urbanization on stream hydrology has been studied for years. Urbanization tends to result in more IC. IC is a description of land cover such as roads, parking lots, and building rooftops that changes the natural dynamics of the hydrologic cycle. The National Academy of Sciences in their report "Urban Stormwater Management in the United States" (NAS, 2008) highlighted the importance of stream flow, recognizing that urbanization has resulted in radically different flow regimes than prior to urbanization and that those changes have resulted in "*urban stream syndrome*", a condition of ecological degradation of streams draining urban land. IC can dramatically change the magnitude, velocity and rate of stormwater runoff.

The amount of IC in a watershed is therefore a key landscape indicator that directly influences watershed hydrology. When a watershed is covered with impervious surfaces, precipitation that would normally infiltrate into the ground instead flows over impervious surfaces as stormwater runoff and is discharged directly into to receiving waters. This alteration of natural hydrologic process reduces runoff lag time (the amount of time it takes precipitation to reach the stream), increases the peak rate of streamflow discharge, increases stream flashiness, increases both the number of bankfull/sub-bankfull events and low-water streamflow, and causes increases in the scouring and incision of the stream channel. Numerous studies have shown that a high percentage of IC in a watershed leads to streams that frequently become physically unstable due to heavy erosion and sedimentation which, in turn, can degrade habitat quality below the level necessary to sustain a broad diversity of aquatic life. **Table C-1** summarizes the resulting stream flow impacts caused by an increase in IC within a watershed.

Table C-1: Increase in Imperviousness and Resulting Stream Impacts

Increased Imperviousness Leads to:	Resulting Impacts			
	Habitat Loss	Erosion	Channel Widening	Streambed Alteration
Increased Runoff	X	X	X	X
Increased Peak Flow	X	X	X	X
Increased Peak Flow Duration	X	X	X	X
Decreased Base Flow	X			
Increased Sediment Loadings	X	X	X	X

In fact, more than 200 scientific articles show that IC is an excellent indicator of urban development impacts on instream aquatic life. Numerous studies have noted that several stream quality indicators decrease as IC levels increase. These studies agree that this trend becomes more evident when IC is within the 10-25% range and that impairment is almost assured when the watershed IC exceeds 25% (Arnold and Gibbons, 1996, CWP, 2003, 2005, Klein, 1979, Miltner et al. 2004).

To help understand the relationship between IC and flow in the Accotink Creek watershed, statewide data was evaluated using a regression analysis between IC levels and DEQ Stream Condition Index (VSCI). Calculation of a VSCI score incorporates eight standard metrics, based on the abundance and types of macroinvertebrates present at each monitoring station. The multiple metrics evaluated together give an overall indication of ecological integrity when compared to a reference condition, which is based on an aggregate of unimpaired streams in non-coastal Virginia.

The analysis uses the DEQ statewide VSCI scores for 2004-2008 along with the DCR National Watershed Boundary Dataset (NWBD-Virginia portion). The NWBDs, which are official hydrologic unit designations within Virginia, were combined with the 2004-2008 VSCI statewide database and the 2005 Department of Forestry (DOF) land use data. The objective was to estimate specific the land use distributions at the DEQ station included in the 2004-2008 VSCI database. When two or more VSCI stations were located within the same NWBD, the land use distribution at the lower station was assigned to that particular NWBD.

DOF's land use data was developed through segment-based classification of Landsat satellite imagery acquired from 03/10/2002 to 05/08/2005, which provides an up-to-date land use distribution for the Commonwealth of Virginia. The DOF land use classifications provide break-downs of the urban land covers (pavement, rooftop, and residential/industrial as opposed to the low/medium/high intensity development in the NLCD classifications). Because the DOF land-use GIS data is statewide and provides this level of specificity, it was deemed appropriate for estimating the level of imperviousness for all stations in the DEQ VSCI database located within the watershed boundaries. Impervious cover was estimated by assigning levels of imperviousness to each urban classification in the DOF land use data. Pavement and rooftop land uses were assigned 100% imperviousness. The residential land use was category was assigned 60% imperviousness since the DOF land use data does not distinguish between high-density, medium-density, and low density residential area.. The average reported imperviousness for these land use categories is around 60% (Maidment, 1993; Chow, 1964).

The resulting data (level of imperviousness and VSCI scores) was then disaggregated by ecoregion prior to perform the statistical analysis. The Accotink Creek watershed is located in the Northern Piedmont, Piedmont, and Southeastern Plains Ecoregions; USEPA Level III classification numbers 64, 45, and 65, respectively. The statistical package Minitab® (Version 14) was used to develop the regressions in order to develop correlations between the VSCI score and the level of imperviousness using data for stations within each Virginia Ecoregion. **Table C-2** depicts the regression results for all the Ecoregions in Virginia.

Table C-2: Impervious Cover and Degree of Impairment Relationships in Virginia

Ecoregion	Number of Data Points	R-Square (%)	Range of Observed Values	
			VSCI	IC (%)
Blue Ridge	43	27.3	50.2 - 84.5	0.5 - 12.2
Central Appalachians	54	27.7	35.6 - 75.7	0.8 - 11.1
Northern Piedmont	98	49.7	31.8 - 78.5	1.0 - 82.1
Piedmont	176	63.2	26.7 – 76.7	1.0 – 66.0
Ridge and Valley	223	69.6	24.1 – 81.8	0.0 – 62.0
Southeastern Plains	64	3.9	17.6 - 78.6	1.2 - 78.2

The analysis of the results indicates that the robustness of the regressions between IC and VSCI is dependent on the number of samples in each Ecoregion. Moderate to acceptable R-Square values results are achieved for the Ridge and Valley Ecoregion (223 data points with an R-Square 69%); the Piedmont Ecoregion (176 data points with an R-Square 63%), and Northern Piedmont Ecoregion (98 data points with an R-Square 49%). All the regressions for the other Ecoregions with a dataset fewer than 54 points show a weak to a non-existent correlation between VSCI and IC. **Table C-2** also indicates that there is a good correlation between VSCI and IC using the data in the Piedmont Ecoregion where the majority of the Accotink Creek watershed is encompassed. The regression for the Piedmont Ecoregion is shown **Figure C-7.**

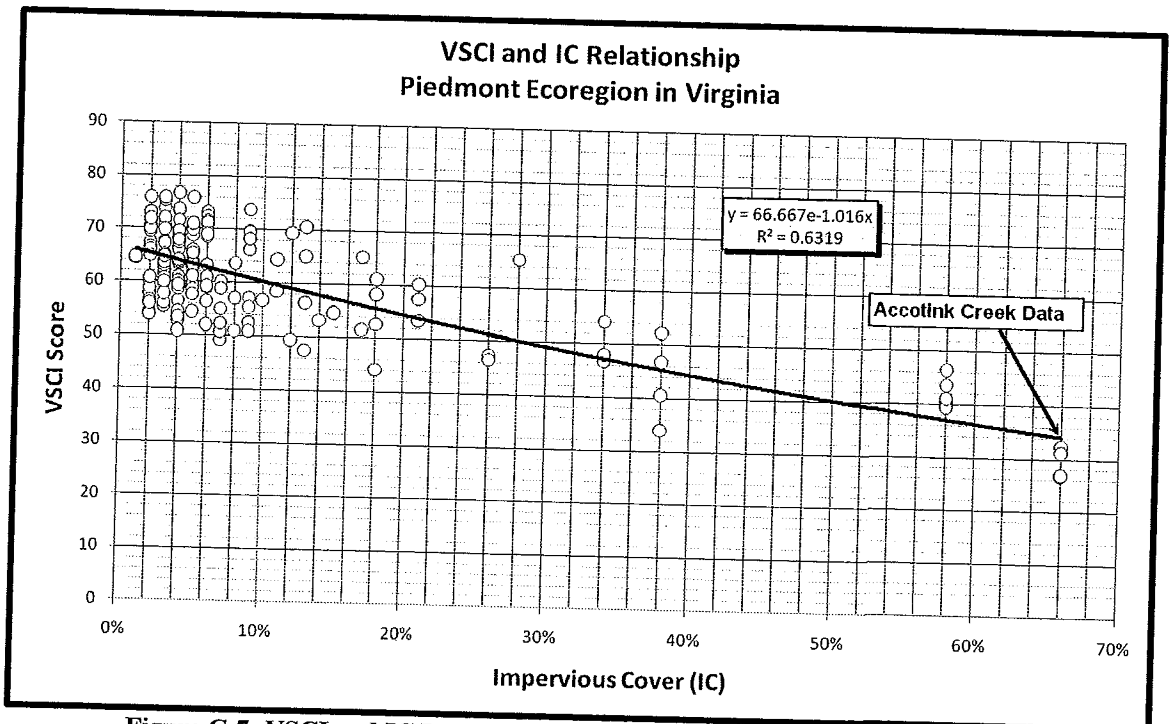

Figure C-7: VSCI and IC Relationship for the Piedmont Ecoregion in Virginia

It is important to note that the Accotink Creek data points in Figure C-1 have a high percentage of IC and a low VSCI score. Using the VSCI score of 60 (Streams that have a VSCI score of 60 or greater are considered to be non-impaired, while streams that score less than 60 are considered impaired), **Figure C-7** also indicates that the IC target for an impaired streams is around 10 percent. This result agrees with other studies that found impairments in the 10-25% IC range.

This information further lends support that the urbanization and significant IC within the watershed is contributing to the degradation of Accotink Creek. The amount of IC disrupts the natural hydrological cycle and is part of the problem and the solution for the TMDL implementation. This information is critical for any stream restoration efforts as a result of this TMDL.

Conclusion

Over the last decade, there has emerged a widespread recognition and a strong scientific consensus that a natural flow regime plays a critical role in sustaining ecosystem integrity within rivers and streams. Studies document many instances of the ecological harm caused by human alteration of flow regimes. The data provided in this TMDL and Appendix supports the consensus found in the literature that there is a strong relationship between the impairments in Accotink Creek, sediment and stream flow. Further, consideration of impervious cover (IC) within the watershed may serve as an effective tool to reduce the stream flow and restore a more natural hydrologic condition.

APPENDIX D

Relative Bed Stability Data Collections in Accotink Creek

MEMORANDUM
VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY
Blue Ridge Regional Office

3019 Peters Creek Rd. Roanoke, VA 24019

SUBJECT: 2008 LRBS Data Collections on Accotink Creek

TO: Katie Conaway, Jeanne Classen, Gregory Brown, and Bryant Thomas

FROM: Jason Hill

DATE: December 11, 2008

What is Relative Bed Stability (RBS)?

Excess sedimentation is one of the most prevalent and harmful stressors to benthic macroinvertebrate communities (VDEQ 2008, ODEQ 2007, Van Sickle 2006, USEPA 2006). Excess sediment fills interstitial spaces in the stream substrates used by aquatic organisms for habitat. Until recently, tools for rapidly quantifying sedimentation impacts in streams have been inadequate. Methods existed for describing dominant particle size, but it was difficult to differentiate between natural conditions and man-made problems. Virginia has a variety of stream types; many are naturally sand/silt bed streams, so simply measuring the size of the sediment particles cannot differentiate natural and human-influenced sediment load.

United States Environmental Protection Agency (USEPA) researchers have developed a tool for predicting the expected substrate size distribution for streams (Kaufmann 1999, Kaufmann 2008). This method incorporates stream channel shape, slope, flow and sediment supply. The method calculates a 'stream power' based on channel measurements to predict the expected sediment size distribution. The logarithm ratio of the observed sediment to the expected sediment is a measure of the relative bed stability (LRBS). LRBS numbers around zero indicates the stream is stable (i.e. the stream is carrying the appropriate mean particle size for its calculated stream power). Increasingly negative LRBS numbers indicate excess sediment, while positive LRBS numbers signify sediment removal. This sediment removal leads to "stream hardening" which may indicate a stream that has eroding banks and stream bottom from altered hydrology. Another example of "stream hardening" occurs just downstream of some large reservoir projects. The reservoir acts as a large sediment trap, leaving the downstream river reach abnormally devoid of sediment.

2008 LRBS Data Collection on Accotink Creek

The relative bed stability data collected by Northern Regional VDEQ biologists on Accotink Creek allows the calculation of several quantitative habitat metrics. These metrics include percent slope in reach, mean particle size, logarithm Relative Bed Stability, and percent fines (particles less than 2 mm). Quantitative habitat metrics can be compared to statewide distributions (example in Figure 1) calculated from Virginia' Freshwater Probabilistic Monitoring Program (VDEQ 2008). This allows the data collected from Accotink Creek to be compared statewide.

Figure D-1. Cumulative Distribution Function of Percent Fines in Virginia

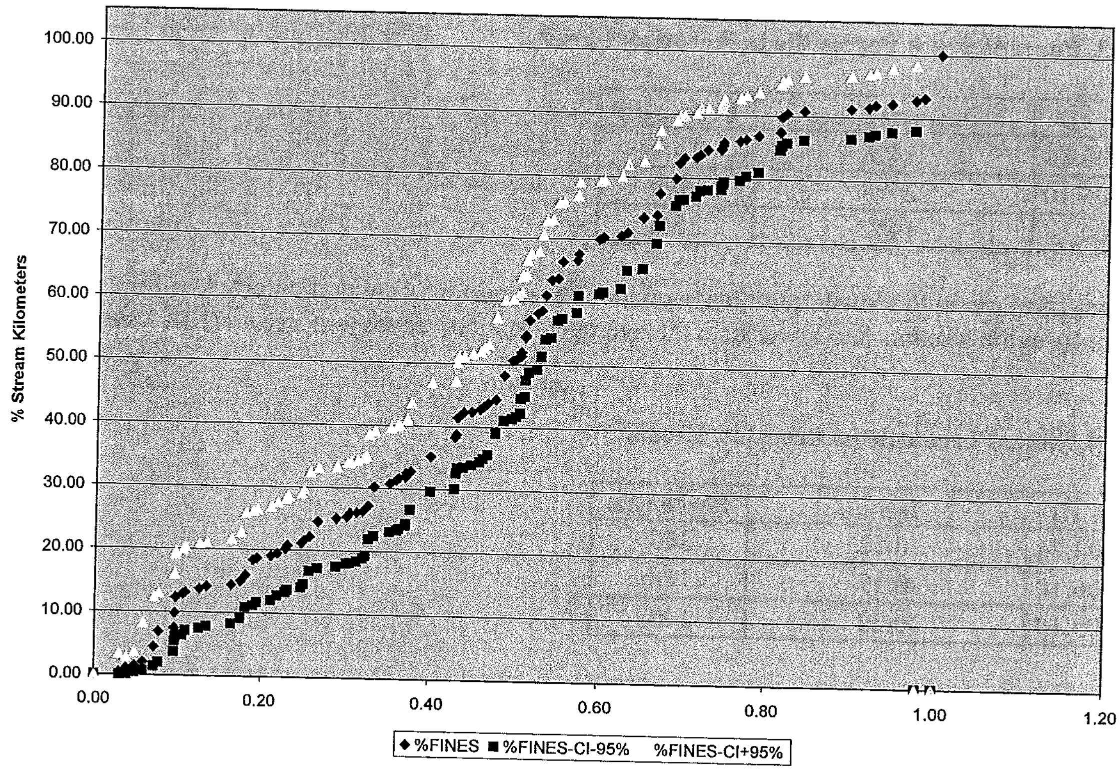

Table D-1. Mean Particle Size Percentile in Accotink Creek.

Station ID	Mean Particle Size	Percentile
1AAC004.84	1.17	73rd
1AAC006.10	1.35	79th
1AAC009.14	1.44	83rd

The mean particle size in Accotink Creek at stations 1AAC006.10 and 1AAC009.10 is within the cobble (64 to 250 mm) range. The mean particle size in the upper Accotink stations is greater than the average mountain ecoregion stream. (Hill Memo 2007). These particle sizes are in the upper quartile statewide. At station 1AAC004.84 the meant particle size is closer to course gravel.

Table D-2. LRBS Percentile in Accotink Creek.

Station ID	LRBS	Percentile
1AAC004.84	-0.04	88th
1AAC006.10	0.56	95th
1AAC009.14	0.72	99th

The LRBS at stations 1AAC006.10 and 1AAC009.10 are some of the most positive LRBS numbers recorded statewide. The lower station 1AAC004.84 is more normal, although high for LRBS scores in Virginia. Positive LRBS numbers indicate the stream has less sediment than expected based on the stream morphology.

Table D-3. Percent Fines Percentile in Accotink Creek.

Station ID	Percent Fines	Percentile
1AAC004.84	18%	15th
1AAC006.10	24%	20th
1AAC009.14	19%	18th

The percent fines are in the lower quartile statewide. These numbers are particularly low for piedmont ecoregion streams and lower than the average mountain ecoregion stream (Hill Memo 2007).

Table D-4. Slope Percentile in Accotink Creek.

Station ID	Slope	Percentile
1AAC004.84	0.52	30th
1AAC006.10	0.17	11th
1AAC009.14	0.22	14th

High slope streams in the western mountains of Virginia explain some naturally high LRBS scores. High slope streams tend to have higher stream powers and are consequently dominated by larger particle sizes. Accotink Creek's slope is moderately low and does not explain these excessively stable LRBS numbers.

It appears altered hydrology has led to a scoured stream, which leaves behind a higher than expected median particle size. In addition, fine sediment has been transported out of the reach and led to some of the highest LRBS scores in the Virginia RBS habitat database. Sediment that erodes from the Accotink Creek watershed is not deposited in these sampled reaches.

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